This expert witness report from Steven Flanagan has been redacted under the Freedom of Information Act, 2014 (FOI) to remove references to personal information.

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RE: ACCIDENT AT SMILER ROLLERCOASTER, ALTON TOWERS, 2nd JUNE 2015

EXPERT'S REPORT

October 2015

PREPARED AT THE REQUEST OF THE HEALTH AND SAFETY EXECUTIVE

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REPORT AUTHOR

1) I am Stephen Flanagan, trading as 'Stephen Flanagan, Consultant', of [redacted] I provide technical and para-legal support in matters arising under Health and Safety Law, plus expert opinion in matters within my field of expertise.

2) Between 2002 and 2013, I was employed as a Principal Inspector of the Health and Safety Executive (HSE), based at their Newcastle under Lyme office. I joined HSE as an Inspector enforcing occupational health and safety law in January 1990. I hold a Postgraduate Diploma in Occupational Safety and Health. I have attended training courses in Safety Engineering and Ergonomics.

3) Between 1990 and 2013, I was responsible for regulation of a wide range of private and public sector industries. As an Inspector, this was by direct inspection and investigations within those industries, and later as a Principal inspector, largely by management and supervision of Inspectors exercising that role.

4) For a period of approximately 15 months from 2008 to 2009, I performed the role of Head of Operations for the West Midlands area of HSE's Midlands Division.

5) I inspected fairgrounds and amusement parks, and investigated fairground accidents and incidents between 1991 and 2013. I have headed a national team of HSE

Inspectors specifically tasked with conducting audits of the inspection bodies operating under the Amusement Devices Inspection Procedures Scheme (ADIPS).

6) Prior to, and during the whole of my time as a Principal Inspector, I had management responsibility for the activities of the HSE Midlands Division members of the National Fairgrounds Inspection Team (NFIT), and have provided support to NFIT nationally. I have delivered extensive training to Inspectors on the topic of fairground safety, over a number of years. I have delivered a number of Seminars on fairground safety to the fairgrounds industry. I have been consulted on the content of HSE's published guidance for the fairgrounds industry, in particular, HSE publication HS(G)175, 'Fairgrounds and Amusement Parks: Guidance on safe practice' (HSG175). A copy of this guidance is contained in Appendix 3 of this report.

7) I have provided, and continue to provide, expert opinion in relation to a number of prosecutions following incidents in the fairgrounds industry and other industries.

INSTRUCTIONS AND DOCUMENTS SUPPLIED

8) I have been provided with the following documents:

    i. Copies of Statements as listed in Appendix 1 of this report.

    ii. Copies of Documents as listed in Appendix 2 of this report.

9) My instructions, by contract dated 8th October 2015, are to give my expert comment upon "the systems of work and the supporting arrangements for providing information, instruction, training and supervision to relevant staff operating the Smiler ride on and before the 2nd June 2015 at Alton Towers". I have been

particularly asked to "consider the information provided, so as to form opinion on the level of compliance with established benchmarks, including the assessment of risks and commensurate measures for the control of those risks."

FACTUAL SUMMARY

10) The Smiler rollercoaster was in operation during 2nd June 2015, under the control of [redacted], a designated operator of the ride. Shortly after 13.00hrs, she became aware of a slow flashing warning light on the ride's main control panel, indicating a 'fault' condition. Guests were removed from the ride, and she called for assistance from 'Technical Services'. [redacted] and [redacted] mechanical engineers, attended from close by. [redacted] dealt with the fault by moving the key-controlled mode switch from automatic (mode 3), to 'maintenance', or manual (mode 2), and acknowledging or 'clearing' the fault code, thus re-setting the control system to its normal running condition.

11) [redacted] and [redacted] had earlier been told that the Smiler would need a fifth train adding to the track, in addition to the four it had been operating with that morning, because of visitor numbers. [redacted] then decided that there was the opportunity now, whilst no passengers were on the ride, to put the additional train onto the ride. [redacted] informed central 'Control' that the fifth train was to be added. During the process of adding a fifth train, it became necessary to send an empty train around the track. This was dispatched, but after leaving the first lift and progressing along the first, long, unpowered section, it failed to engage properly with the second lift. The main control panel indicated a 'block fault', i.e. the ride's control system

had registered that a train had failed to clear the track section between the first and second lift.

12) [redacted] and [redacted], electrical engineers, arrived at the ride, and began to assist. They were not aware that a fifth train had just been added to the track.

13) [redacted] and [redacted] went out to the train at the second lift, to push it on into the lift chain mechanism. [redacted] in communication with them, operated the control panel in manual mode, and the car was successfully sent on through the ride track, with the result that all cars were now back in the station or waiting areas.

14) [redacted] then sent one empty train up the first lift, in order to establish that the ride was now operating normally. Unknown to those present, this car failed to clear a loop on the section of track between the first and second lifts, and rolled back, coming to rest in one of the track 'valleys'. The ride was then handed back to the control of [redacted] who began to load the first passengers. The first loaded car was sent to the top of the first lift, which triggered a 'zone stop' alarm on the control panel. [redacted] and [redacted] then resumed control. [redacted] identified the positions of the four trains which he believed were on the track by studying the control panel, then went out to the satellite control panel out on the track, close to the foot of the second lift. There was no train present at the foot of lift 2. He failed to notice the stalled train in the track valley. His function was to press a button on that control panel, simultaneously with [redacted] pressing of a button on the main control panel, which would clear the 'zone stop'. This was done, the consequence being that

the control system would no longer regard the section of track between the first and second lifts as being occupied.

15) [redacted] then asked central 'control' for a 'Code Zero' permission, which would enable her to operate the ride in 'mode 4', i.e. evacuation mode. This would command the control system to systematically return all trains to the station, beginning with the train most advanced through the track, and working backwards. With permission granted, she began the process. In accordance with the programmed logic of the evacuation mode, the control system began by moving the train which it believed was furthest through the ride sequence, i.e. the train loaded with passengers held at the top of lift 1. This was sent on, and crashed into the stranded car in a 'valley' between the two lifts.

COMMENTARY

Safety at Fairgrounds

16) The operation of fairground rides is generally considered to be a high hazard activity. That is to say that an untoward event such as the one occurring on the Smiler ride would potentially have serious consequences, involving serious multiple injuries or fatalities. In such situations, it is important that the risk, or likelihood, of such an event actually occurring is reduced to the lowest degree reasonably practicable, and a higher level of precautions would generally be expected than in situations of low hazard, i.e. where any harm which materialised would be minor.

17) In recognition of this, HSE has worked with the industry to produce detailed guidance on the precautions to be taken. The main guidance is set out in HSG175.

18) HSG175 sets out a 'System for safety of attractions', consisting of a series of 'steps' and 'checks' intended to ensure safety from design of a fairground ride, through to the ride's operation and maintenance. This can be found in tabular form (table 1) on page 7 of HSG175. The requirement for 'checks' is intended to avoid the situation where defects, faults and errors are not detected. I consider that this is consistent with the usual goal of a Safety Engineer, which is the avoidance of conditions where a single failure (whether a 'hardware' failure or a human behavioural failure) leads directly to a high hazard situation without opportunity for intervention or correction.

19) HSG175 is written as generic guidance, but it does point towards issues which are relevant to the matter under consideration, with some very basic advice. At paragraph 252 it states *"General information and training for all employees involved in running a device need to cover at least the following areas: ……………………how to deal with defects and malfunctions"*.

20) The approach by HSG175 of requiring steps and checks can be illustrated with the example of ride design. The requirement (or 'step') in table 1 is for design *"by competent designers with knowledge of the relevant standards"*. The additional requirement is for an independent **check** on the soundness of the overall design concept, by the process known as 'Design Review'. HSG175 goes on to provide advice on design under the heading of 'Design risk assessment (DRA)', at paragraphs 34 and 35. These state *"The fairground industry publication 'Safety of amusement devices: Design' defines a design risk assessment as: 'the process of assessing the hazards that an amusement device might pose, the likelihood of those hazards posing a risk and the control measures that are necessary to control those risks adequately.*

As a fundamental element of the design process, you should assess all the risks associated with the design, as well as those risks arising out of the activities specified in paragraph 29 and record this in the DRA. It should be used to help specify the safety functions of the amusement device". Paragraph 29 refers to the need for the design to aim to ensure safety during assembly, dismantling, transport, installing, operation, cleaning, maintenance, inspection, testing and use by the public.

21) The joint ADIPS/HSE publication 'Safety of amusement devices: Design' (SADD) gives detailed guidance on the conduct of a Design Risk assessment, and at chapter 9, paragraph 15(g), emphasizes the value of use of analytical techniques such as 'Failure Modes and Effects Analysis', as part of the design risk assessment process. A copy of SADD is attached to this report at appendix 4.

22) Failure Modes and Effects Analysis (FMEA) is widely used in the design of complex plant and machinery in high hazard situations. It considers the many ways in which plant or machinery may go wrong, and the consequences of such failure, and seeks to identify means of ensuring that such failures do not lead to immediate danger.

23) FMEA is founded upon the use of a number of fundamental principles used by the safety engineer. I would summarise the key principles as:

   i. <u>Redundancy</u>. It is the nature of many components of a device, for example, a fairground ride, that the failure of a single component will occur at random. If the component selected has an acceptably low random failure rate, then a high level of safety integrity can be introduced simply by doubling up the provision of the key component, in a design where either of the two components, if functioning, can maintain safety independently. A simple example of this from everyday life would be the introduction of 'dual-circuit' brakes on motor cars. With this development, safety was no longer reliant on a single hydraulic circuit.

ii. Diversity. This principle recognises that situations can exist where two or more device components which apparently operate independently of each other, may both be affected by the failure of some other element of the design. Returning to the example of motor car brakes, even if a dual circuit system is fitted, a failure to maintain an adequate supply of brake fluid in the reservoir, or the loss of containment of the reservoir (e.g. a leak), could lead to the non-functioning of both hydraulic circuits, and complete loss of braking. This type of failure is referred to as 'common mode' failure, or 'systematic' failure. The safety engineer's solution to this problem is normally to introduce additional components or systems which do not rely upon the same aspects of the design for their continued function. This is the principle of diversity. The motor car braking example would be that in addition to the hydraulic footbrake, a cable-operated handbrake is also provided, which is not reliant upon the hydraulic system.

iii. Failure to Safety. If the design can be arranged such that failure of key components will be a failure to a safe condition, then this will amount to inherently safe design. A motor vehicle example would be the braking systems of Large Goods Vehicles, which are air/spring systems, and can be described as 'air off, spring on', such that loss of the air supply leads to the brakes locking on, rather than loss of braking functionality. Good design may also include provision for faults to be self-revealing. Taking the example of two identical components, with an acceptable random failure rate, these will normally be arranged such that either of the components can independently maintain safety. However, if the design does not lead to the initial fault being revealed, then the device will continue to function with one failed component, hence no redundancy, until the second component fails to danger. In complex designs, it will often be necessary for the device's control system to include some form of monitoring of the condition of safety critical components, in order to deal with this issue.

iv. Hierarchy of control measures. Another fundamental principle is that of selecting inherently more reliable control measures or components over those less reliable. A general rule adhered to is that properly designed and constructed hardware control measures will be inherently more reliable than reliance upon human actions. For example, it is understood that adequate physical guarding of dangerous parts of machinery is inherently more reliable than issuing instructions to workers to 'keep your hands out', or the like. Therefore, in situations where it is necessary to rely on human actions in high hazard systems, it is all the more vital to apply the safety engineer's principles of redundancy, diversity, and failure to safety to the systems of work which need to be created to direct human actions.

Safety of Rollercoasters

24) The principles of safety engineering which I have outlined above have been successfully applied to the design of fairground rides, probably most notably in the

case of rollercoasters. Whereas the public perception of the hazards associated with rollercoasters may be focused on the danger of a train parting company with the track, in reality, the bigger, and more difficult to resolve issue has always been the hazard of trains colliding on the track.

25) Considerations of 'throughput', (numbers of riders passing through the ride) have tended to lead to designs which can operate with multiple trains sharing the track. This can only be achieved safely if the ride is operated to a 'block system', where conceptually, the track is separated into sections, or 'blocks' and a control system prevents more than one train ever being in a given block at any one time.

26) In the early years of rollercoaster design, control systems were often rudimentary, and involved a large degree of human input for their functioning. For example, the collision accident at Battersea Park, London which killed five in 1972 occurred on a wooden rollercoaster which required manual braking under the direct control of a ride attendant. With increasing complexity, control systems have become more sophisticated, and are now almost universally not primarily reliant on human intervention.

27) Following a period of control system design which relied upon 'hardwired' relay-logic systems, there is now an almost universal reliance upon computer based control systems, because it produces a cheaper, more compact solution.

28) Conceptually, a well-designed system, would incorporate the design principles which I have set out above. The system will be designed around Programmable Logic Controllers (PLC). These are specialised computers, with a high degree of initial integrity. Redundancy is generally achieved by configuring the control system to

incorporate, conceptually, two discrete channels of control. This may require the use of two PLCs, and each of the safety critical input devices providing information to the PLCs will be doubled up. Typically this will involve proximity switches detecting the entry and exit of trains from sections of the track being provided in pairs. Each of the pair will provide an input into one of the channels of control. It is recognised that computer software is prone to 'systematic failures' i.e. faults which will always materialise under particular conditions, and so the use of dissimilar software in each channel of control, or the Quality Control of software, is common. Further, 'failure to safety' is generally ensured by a constant 'cross-monitoring' between the two channels of PLC control, which will detect any difference in status between the two channels of control, and shut the ride down to a safe condition. Good control system design will also recognise the advice contained in Chapter 1 of the SADD guidance, at paragraphs 47 and 50, when considering an appropriate hierarchy of control measures.

29) Paragraph 47 states *"Training, and experience might reduce the risk but none of these factors should be used as a substitute for risk reduction by design or safeguarding where such safety measures can be reasonably practicably implemented. Due to the exposure of large numbers of members of the public, inappropriate reliance should not be placed on ride operators/attendants having to develop an unreasonable degree of skill or acquired knowledge to ensure public safety".*

30) Paragraph 50 states *When safety measures include:*

a. *work organisation,*

b. *correct behaviour,*

c. *diligence,*

d. *application of personal protective equipment,*

e. *skill or training,*

the relatively low reliability of such measures, as compared to proven technical safety measures, should be taken into account in the risk estimation. Where it is reasonably practicable to employ technical and or physical safety measures this should be done in preference to relying on those measures listed above.

31) The SADD guidance also provides further advice on the limitations of reliance on human actions as a means of ensuring safety, by reference to 'Human Factors', in paragraphs 45 and 46 of Chapter 1. Paragraph 45 states, *"Human Factors can affect risk and shall be taken into account in the risk estimation. This includes, for example:*

a. *Interaction of persons with the amusement device;*

b. *Interaction between persons;*

c. *Psychological aspects;*

d. *Ergonomic effects;*

e. *Capability of persons to be aware of risks in a given situation (e.g. in relation to ride operators or maintenance staff) depending on their training, experience and ability.*

32) Paragraph 46 states, *"The estimation of the ability of exposed staff shall take into account the following aspects:*

a. *Application of ergonomic principles in the design of the device;*
b. *Natural or developed ability to execute the required tasks;*
c. *Awareness of risks;*
d. *Level of confidence in carrying out the required tasks without intentional or unintended deviation;*
e. *Temptations to deviate from the prescribed and necessary safe working practices.*

The design of the Smiler rollercoaster

33) When commenting, in line with my brief, on the adequacy of the systems of work in place for operation of the Smiler ride, it is worthwhile considering initially whether the ride design was adequate, when assessed against the above mentioned criteria as applied by safety engineers.

34) The literature supplied to me which originates from the manufacturer, Gerstlauer, does not contain a comprehensive description of the control system for the Smiler. However, there is mention of an 'Allen Bradley' PLC. I am aware that this is a reference to a manufacturer of a type of PLC much favoured by rollercoaster manufacturers. Exhibit LM/47f, an Alton Towers risk assessment for ride maintenance, identifies the PLC as being 'dual process'. Based on this, there would appear to be a control system providing two separate channels of control.

35) Exhibit LM/21 'Infinity Coaster the Smiler Original Operating instructions', provides a brief description of the 'block system', at page 57. This document is clearly a

translation from the original German, with the limitations of that, but I derive the meaning from it as i) entry of a train into a block is monitored by a pair of proximity switches, and a signal from at least one of the switches is sufficient for the control system to regard the train as having entered the block, and ii) exit of a train from a block is monitored by a pair of proximity switches, and a signal from both of the switches is required for the control system to regard the train as having left the block. This demonstrates the correct approach to ensuring safety through 'redundancy', using 'AND' and 'OR' logic in the control system appropriately, i.e. OR logic for situation i) above, and AND logic for situation ii) above.

36) From this, and consideration of the witness statements of ride operators and Technical Services engineers, I conclude that the control system appears to have the necessary attributes to allow the ride to be run safely in an automatic mode, under normal conditions.

37) It is also apparent that the ride designers have applied the principles of safety engineering and the science of Ergonomics to the interface between the ride control system and its human operators, and have paid due regard to the provisions of the SADD guidance, chapter I, paragraphs 47 and 50 as referred to above, by seeking to limit the potential for human error.

38) The first example of this which I cite is the configuration of the control system regarding the arrangements for loading passengers into trains in the station. Ensuring that passenger restraints are properly closed is safety critical, and I note that the usual modern convention of monitoring the position of each restraint, and providing an input to the control system, is followed. This, together with a physical check by ride

attendants (as required by HSG175, and introducing redundancy and diversity) largely eliminates the possibility that a passenger could ride without the restraint being locked. However, the need to physically check restraint locking brings the ride attendants into close contact with the train. The consequence of a train being dispatched prematurely in those circumstances could be serious, in terms of injuries to ride attendants. Hence, dispatch is only allowed by the control system if it receives simultaneous inputs by button pressing by the ride attendants and the ride operator. This largely eliminates the possibility of the ride operator dispatching a train prematurely, i.e. once the restraints have locked, but before the attendants are clear of the train. This builds in a second layer of control measure, using the 'AND' logic principle.

39) The second example I cite is of the control system configuration relating to the 'clearing' of block faults. This ride will indicate a block fault in the event that the signals received for relevant proximity switches indicate that a train has failed to exit a block. Because the control system does not, and cannot, have eyes, the signals from the proximity switches are a proxy for reality, and may not always accurately reflect reality, and so it is designed to err on the side of caution. This can be regarded as an application of the concept of 'failure to safety'. Therefore, in order for the system to safely restart, human intervention is necessary. A person or persons must satisfy themselves that the relevant block is empty or has been emptied. This ride's control system has been configured with satellite control panels at suitable locations around the track. It is necessary for the person in charge of the main control panel, and a second person located at the relevant satellite control panel, to press buttons

simultaneously. The thinking behind this requirement seems to be that it requires a person to physically visit the area of the block to be 'cleared' thus encouraging the necessary visual check. This is reinforced by the manufacturer's supplied literature pointing out this need. Without this, there is the danger that persons may rely too much on the indications of the rides condition as shown on the main control panel, which does not always represent reality; or, as occurred in this accident, there could be undue reliance on an unconfirmed presumption (in this case as to the number of trains on the track).

40) The third example I cite is the provision of an 'evacuation' mode, selectable via the mode switch located on the main control panel. When, for breakdown or maintenance purposes, it becomes necessary to take all passengers off the ride, the use of the automatic running mode is not appropriate, because it would continue to send cars around the track, and reaching the desired end result of all the cars being empty in the station area could be difficult to achieve. The evacuation mode provides a relatively straightforward means of achieving the evacuation simply and quickly, with the minimum potential for human error. It represents good design. However, the safe use of the evacuation mode is dependent on the proper following of the procedure for clearing block faults, as I have described in paragraph 39 above. If the control system is not aware of the true position of all trains, it cannot operate the evacuation procedure safely. This is central to the immediate causes of the accident on the Smiler.

41) In summary, the Smiler ride appears to me to be a well-designed ride which has been through a process of design review, as evidenced by exhibit LM/32 'Declaration of

Operational Compliance'. Its design incorporates features designed to limit the need for human intervention during operation, and thus to reduce the potential for human error. The design also recognises the limitations of human actions as a control measure, and follows sound ergonomic principles by providing a person/machine interface which encourages informed decision taking which relies on more than one individual acting alone.

Operating Procedures for the Smiler Ride

42) However well a rollercoaster may be designed, with current technology, significant human intervention will be required, and it is vital that this is done safely.

43) This issue is addressed by the science of Ergonomics, which is often expressed as the science of 'person centered design'. Such design has obvious benefits related to usability, efficiency, and the minimising of the potential for error. A very simple example would be the fact that it is now almost universal that the direction indicator control on motor cars has been standardised to a stalk to the left hand of the steering wheel. This has improved the likelihood that a motorist will give a correct signal at the appropriate time (rather than operating the windscreen wipers), particularly when driving an unfamiliar car.

44) In the work environment, much attention is given to situations where individuals have to perform complex tasks, because of the raised potential for human error. Control measures can include careful design of the person/machine interface (for instance the provision of a 'mimic' or graphic display showing the status of the Smiler ride), realistic design of the task which avoids overburdening the worker, and the use of a technique commonly referred to as 'Task Analysis'.

45) Task Analysis attempts to review, define, and standardise procedures. In the language of industry generally, it can be expressed as the laying down clear and defined systems of work. Where such systems are safety related, they can properly be called 'safe systems of work', as required by the Health and Safety at Work etc. Act 1974. Task Analysis is achieved by breaking down the required task into its component parts, ordering them in safe and efficient sequence, and making provision for actions to be taken in the event of foreseeable deviations from the norm by any plant or machinery being worked with. Typically, clear and emphasised 'do's' and 'don'ts' will be included. Workers would be trained in the procedure, step by step, and their understanding and capacity to follow the procedure tested. Where safety critical steps in the process are identified, it is common in high hazard situations, to introduce checks on actions, to confirm the absence of error.

46) The routine operation of the Smiler ride is in the hands of staff employed in the Operations Department at Alton Towers. The key document which illustrates the systems of work which they operate to is exhibit LMS/04 'The Smiler Cabin Folder'. This contains the document 'Code of Safe Working Practice – The Smiler 2015'. It is a large document, which reflects the degree of complexity of the task of a ride operator. I consider that it bears the hallmarks of having been produced as a result of a process of Task Analysis. It carefully details the sequences of all the processes or work activities which a ride operator is expected to perform, and puts clear limits to the actions which they are authorised to perform. It is evident that the main limitation placed on operators is the requirement to call in, and pass over control of the ride, to the Technical Services Department in the event of the ride control system indicating a

'fault'. This is a sensible separation of function, because it reduces the overall complexity of task which any one individual has to face, though it brings with it the challenge of the need for effective communications at handover. I note that a ride log was in use on the ride, which could have assisted in this.

47) The documents provided which relate to the training of ride operators, i.e. exhibit LM/33, indicate training and assessment which closely follows the format and content of the Code of Safe Working Practice for the Smiler. There also appears to be ongoing re-assessment of ability to follow the systems of work, at the start of each operating season.

48) In summary, I am reasonably satisfied as to the adequacy of the systems of work, training and on-going supervision of Operations staff, subject to one qualification. This is that the procedures permit the Operator, on receiving control back from Technical Services, to ask 'Control' for permission to undertake a 'Code Zero'. This would be switching the ride into evacuation mode, which is a safe procedure only if the ride control system has an accurate understanding of the location of all cars. The granting of that permission appears to have been a mere formality, with the opportunity to double check the safety of the proposed action lost. Having said that, it should have been possible for Technical Services department to perform such a double check. What remains unacceptable is for nobody to perform an effective double check.

49) The arrangements in place for Technical Services staff (the engineers) are in sharp contrast to those in place for Operations staff.

50) There is no evidence of a structured Task Analysis based approach to their work, though I hold the view that such an approach would be readily achievable, particularly in relation to the safety critical task of dealing with ride 'faults'.

51) Whenever the Smiler ride displayed a 'fault' it was vital that the appropriate checks were diligently made, so as to bring the ride to a safe condition without harming passengers. This was a process which could have been defined, via Task Analysis.

52) The documents supplied indicate a quite different approach by the Technical Services Department. Training tended to be delivered by observation of and working with, existing engineering employees. Such an approach is not systematic, and tends to pass on bad practice as well as good. It also leads to staff with varying degrees of knowledge, and inconsistent beliefs. For instance, [redacted] electrical engineer, states, '[redacted]" He also states '[redacted]

[redacted] The emphasis in the department was upon skills, experience, competence and qualifications. This would be commendable if it were the case that such attributes in a person guaranteed the absence of errors. If that were the case, there would be little or no need, for example, for:

i. Systems of work in hospital operating theatres designed to 'count in' and 'count out' the numbers of swabs and instruments used, in order that surgeons do not leave them inside patients,
ii. Co-pilots double checking the actions of pilots in civil aircraft,
iii. Independent Design Review of the fairground ride designs of competent ride designers,
iv. Guards, on machinery being operated by skilled and qualified engineers.

53) In my opinion, there were factors present at the time of the accident on the Smiler ride on 2nd June 2015, which were avoidable, and which contributed to causation of the accident:

i. There was no single member of the Technical Services Staff who was required to take, or took, overall control of the process of bringing the Smiler ride safely back into service. Four members of Technical Services Staff, and one operator had varying degrees of input into the process, and none of had a full picture or understanding of the condition of the ride, and what was required for safety.

ii. There were various states of knowledge as to the significance of fault alarms generally, and block faults in particular.

iii. The inadequate state of knowledge of Technical Services staff led to distrust of the otherwise clear fault signals being received from the ride control system. The belief appears to have been formed that that the control system was unreliable, and that their own judgement and decision taking was inherently more reliable. This was perhaps founded upon a failure to appreciate that the control system was of sound design, but was quite correctly designed to 'err on the side of caution' (given that it has to rely entirely on input from sensors, and does not literally have its own eyes). This would inevitably lead to numerous apparent 'false alarms'. The problem then arises that where individuals lack hard rules of behaviour as would be provided by a written system of work, they tend to become habituated to false alarms, and tend to assume that all alarms will be false. (It is understood in the science of Ergonomics that careful design of complex control panels for high hazard applications requires the judicious use of alarms. An overabundance of alarms for minor conditions may 'de-sensitise' operators to alarms generally, i.e. the 'cry wolf' syndrome)

iv. The Technical Services staff were filling in for the gaps in their knowledge with assumptions. Maintenance engineers have to be good fault finders.

There may be limits to what testing can achieve, therefore, some of their fault-finding activity will to be based on making reasonable but unproven assumptions. This is a common technique which is generally effective. If an error is made, the only consequence is usually the need to make fresh assumptions and begin the process again. However, it has no place in a safety-critical situation. There has to be a strict 'deductive' approach of reasoning from demonstrably known facts, to a conclusion. The process might go: 'i) the ride is only safe to operate again if there are no trains in any track blocks, ii) There is clear and confirmed visual evidence that no trains are in track blocks, and iii) therefore, it is safe to operate the ride. This deductive logic can be provided in a suitable written safe system of work.

v. There was no formal control over who was entitled to clear particular faults, or the checks which should be done before clearing them.

54) In consequence of the factors mentioned above, a number of human errors occurred:

i. Error no. 1. The mechanical engineers, [redacted] and [redacted] took the opportunity to load a fifth car onto the track, but failed to communicate effectively, and verify that the electrical engineers, [redacted] and [redacted] understood this, even though they were aware that [redacted] and [redacted] were dealing with a fault. [redacted] states that he told [redacted] whereas [redacted] states "[redacted] and [redacted] states '[redacted] This could usefully be classified as a 'communications' error.

ii. Error no. 2. [redacted] AND [redacted] made assumptions about the number of trains on the ride, without directly verifying it. Although an entry was made in the ride log indicating the addition of the fifth car, neither [redacted] nor [redacted] looked in the log, perhaps unsurprisingly, given that there was no formal written procedure to require them to. Human Factors Ergonomists would tend to classify this error as a 'misperception'.

iii. Error no. 3. When a second block fault occurred between lift 1 and lift 2, it indicated that a train at the top of lift 1 was not being allowed to move into the next section of track. [redacted] states '[redacted] This appears to be another 'misperception', based on poor knowledge of the ride. It appears to me that the error message was indicating that the control system considered the block to be occupied by a train, but because of the previous errors which led to the failure to identify the presence of a fifth train on the track, a false assumption was encouraged. The opportunity to use the CCTV monitors to look at all of the relevant section of track was lost, with [redacted] concentrating solely on the area at the foot of the second lift. Thus, [redacted] was now satisfied that it would be safe to do a block re-set. This could not in itself have led immediately to danger, because of the hardware precautions built into the ride design, which require simultaneous pressing of buttons by two persons.

iv. Error no. 4. [redacted] went out onto the track in order to press the relevant button on the satellite control panel adjacent to the foot of lift 2. The ride designer's intention was that any person pressing that button should have first established beyond doubt that the track section was free of any train. The Gerstlauer 'Original Operating Instructions' (exhibit LM21) state, at paragraph 4.11.3 'Brake Operator Panel 1 – B01 &B03' *"In case of a wrong block occupancy, e.g. after a shut down, the block at the brake can be reset by the panel at the valve box. This can be necessary, if the block is already occupied while no train is present at the block. This case prevents an advancement of the train in the previous block. The responsible person must make sure that there is actually no train present"*. The obvious way to do that was by direct visual observation. However [redacted] had already satisfied himself as to the position of **four** cars. He states '[redacted]

[redacted]' Having made this mistaken assumption, [redacted] went out to the trackside satellite control panel. He states [redacted] This suggests that [redacted] error could also be regarded as based upon 'mistaken priorities'. It is clear that his priority had become getting the ride quickly back into service, and he felt pressure to that effect. The evidence provided to me also indicates that management had set targets for downtime on rides, with bonuses linked to achieving acceptably low levels. There were also 'clocks' in the ride control cabins showing the current performance on downtime.

CONCLUSIONS

55) The Smiler rollercoaster was designed to current standards, and had a sophisticated control system and an ergonomically sound user-interface for operators.

56) The arrangements (system of work, training and supervision) put in place for ride operation by the Operations department were based on sound safety engineering principles, and provided an adequate basis for safe operation in 'normal' mode.

57) The Technical Services department either failed to recognise the safety critical nature of the task of dealing with faults to the ride, or else lacked the safety engineering expertise to devise systems which would deal with the inherent unreliability of relying on human actions in a safety critical situation.

58) The consequence of the Technical Services department's failings was that a situation arose where serious error was a potential outcome, and that outcome materialised.

59) I consider that the additional precautions (which are not intended to be prescriptive, as other similar arrangements could be equally effective) which I have indicated ought to have been taken are eminently reasonably practicable. These suggested precautions are in my report above, and at paragraph 61 below. To a great extent, the reasonably practicable nature of the suggested precautions is illustrated by the fact that the Operations department had such precautions in place, covering a similar situation. Further, since the accident, the Technical Services department has written exhibit LM/56 "Engineering Code of Safe Working Practice The Smiler 2015", which puts such arrangements in place. In addition, the items of correspondence and submissions to HSE relating to compliance with the Prohibition Notice issued for the ride, suggest an ability to devise suitable precautions.

60) Much of the documentation supplied to me which emanates from Alton Towers suggests an organisation which has a well-developed system for safety management, with evidence that monitoring and audit went on. Therefore, I am concerned that

senior management appears never to have become aware, or failed to act upon, the great discrepancy between the robust arrangements put in place by the Operations department and the manifestly inadequate arrangements of the Technical Services department. My recommendation would be that Alton Towers should review the adequacy of its audit arrangements.

61) I am satisfied that if the Technical Services Department had devised a formal written system of work based on Task Analysis and Safety Engineering principles, had trained its staff and monitored their performance to similar standards to those of the Operations department, it is very likely that this accident would have been avoided. Key features of such a system of work could be:

i. One suitable individual should always be appointed or nominated as being in charge of the activity of bringing the ride safely back into use, directing all activity, following a fault condition.

ii. Key decisions potentially affecting the safety of the ride, and requiring formal confirmation of the status of the ride should always be based upon decisions by at least two persons, operating to 'AND' logic, thereby introducing redundancy, and should always be based upon direct observation (thereby reducing the possibility of a common mode failure, i.e. a shared misperception).

DECLARATION

62) I declare that,

i. I understand that my overriding duty, both in preparing reports and in giving oral evidence, is to provide independent assistance by way of objective, unbiased opinion. I confirm that I have complied with, and will continue to comply with that duty;

ii. I have endeavored in my report and my opinions, to be accurate and to cover all relevant issues concerning the subject matter that I have been asked to address. The opinions expressed represent my true and complete professional opinion;

iii. I have endeavored to include in my statement those matters which I have knowledge of and of which I have been made aware, which might adversely affect the validity of my opinion;

iv. I have indicated the sources of all information which I have used;

v. I have where possible formed an independent view on matters suggested to me by others including my instructing lawyers and their clients; where I have relied upon information from others, I have so disclosed in my report;

vi. I will notify those instructing me immediately and confirm in writing if, for any reason, my existing report or opinion requires any correction or qualification;

vii. I understand that my report, subject to any corrections before swearing as to its correctness, will form the evidence which I will give under oath;

viii. I understand that I may be cross-examined on my report by a cross-examiner assisted by an expert;

ix. I understand that I am likely to be the subject of public adverse criticism, if the court concludes that I have not taken reasonable care in trying to meet the standard set out above;

x. I confirm that I have not entered into any arrangement whereby any of my fees are in any way dependent upon the outcome of this case.

Appendix 1 – List of Statements provided

Appendix 2 – List of Documents provided

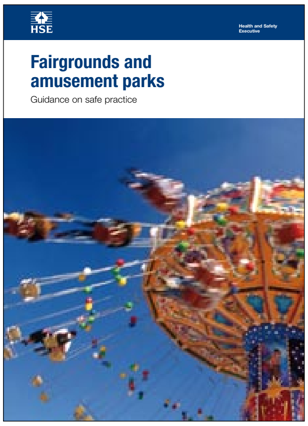
Appendix 3 – HS(G)175 'Fairgrounds and Amusement Parks:

Guidance on Safe Practice

Appendix 4 – 'Safety of Amusement Devices: Design

Fairgrounds and amusement parks

Guidance on safe practice



This is a free-to-download, web-friendly version of HSG175 (Second edition, published 2007). This version has been adapted for online use from HSE's current printed version.

You can buy the book at www.hsebooks.co.uk and most good bookshops.

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Although fairgrounds and amusement parks are relatively safe compared to activities such as driving a car or riding a bicycle, there have been a small number of serious incidents involving employees and members of the public. The Health and Safety Executive has worked with the members of the Fairgrounds and Amusement Parks Joint Advisory Committee to improve standards and to produce this revised guide.

This book incorporates improvements made over several years in this industry's practices. It deals with the safety of employers, employees and the general public using fairgrounds and amusement parks and gives advice on controlling risks, site layout and safe systems of work. It also provides information and guidance on fairground ride design, manufacture, installation, operation, maintenance and inspection.

First published 1997
Second edition 2007

ISBN 978 0 7176 6249 4

This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

Contents

Foreword

This guidance sets out what the Fairgrounds and Amusement Parks Joint Advisory Committee (FJAC) considers are appropriate measures for those involved in the industry to reduce risks, work safely and comply with the law. The following trade associations, in alphabetical order, together with the Health and Safety Executive (HSE) are represented on the committee:

Amusement Catering Equipment Society (ACES)

Amusement Devices Inspection Procedures Scheme
(ADIPS Ltd)

Association of Independent Showmen (AIS)

Amusement and Leisure Equipment Suppliers (ALES)

British Amusement Catering Trade Association (BACTA)

British Association of Leisure Parks, Piers and Attractions (BALPPA)

National Association for Leisure Industry Certification (NAFLIC)

Showmen's Guild of Great Britain (SGGB)

Society of Independent Roundabout Proprietors (SIRP)

About this guidance

Introduction

1 The Fairgrounds and Amusement Parks Joint Advisory Committee (FJAC) has worked for over 25 years to continually improve standards and the exchange of information. Fairgrounds and amusement parks have been shown to be relatively safe compared to such activities as driving a car or riding a bicycle, but there have been a small number of serious accidents involving the general public and employees. Risks can never be eliminated from any aspect of life but need to be managed effectively. This new edition of *Fairgrounds and amusement parks: Guidance on safe practice* (HSG175), first published in 1997 was recommended in the Health and Safety Commission (HSC) Review of Fairground Safety (2001) and incorporates improvements over several years in this industry's practices.

2 This document concentrates on the safety of employers, employees and the general public using fairgrounds and amusement parks, and gives advice on measures to control risks. It provides advice on issues relating to attractions, including operation, maintenance, repairs, and modifications. It also includes advice on site layout and safe systems of work. There is a glossary at the end of the book which explains the terms used.

3 The Health and Safety at Work etc Act 1974 (HSW Act), and subsequent health and safety regulations, place duties on a wide range of people ('dutyholders') according to what they do (see Appendix 1). These include the following:

- **Designers, suppliers, manufacturers, installers and importers** have duties to ensure that the attractions are safe when first supplied and installed, to carry out any necessary research and provide information about safe use, updated in the light of experience. **See Section C.**
- **Organisers** (who can be companies) have overall control of the fairground or amusement park, and have duties concerning safe layout and emergency procedures. **See Sections A, B, D and E.**
- **Controllers** (who can be companies) own or otherwise have control of an attraction, and have a duty to maintain it in a safe condition. **See Sections A, B, C, D and F.**
- **Operators** are in immediate charge of an attraction and have a duty to operate it safely. **See Sections A, D and G.**
- **Attendants** help to operate an attraction, and have a duty to take reasonable care for their own and others' safety, and to follow instructions. **See Sections A and G.**
- **Inspection bodies** (IBs) (who may be companies) provide inspection and testing services. Where they are engaged by other dutyholders to perform specific tasks, it should be established that the particular type of inspection and testing service required is one that body is registered to perform. **See Sections A, C and D.**

4 An individual or company may fall into more than one category. For instance, a person may be the organiser of a fair and both controller and operator of one of the attractions.

5 All the member associations of the FJAC agree that the information in this book is appropriate to help dutyholders meet their legal requirements and expect their members to follow the systems described. Dutyholders are free to meet their legal obligations in other ways, but they need to be prepared to show that what they did was equally effective.

6 The system for safety of attractions set out in this guidance is shown in Section A, Table 1, although not all attractions require all of the actions listed. Section A, Table 2 summarises the actions recommended for different types of attractions.

7 This book does not cover occupational risks such as manual handling, exposure to substances hazardous to health, noise etc. Advice on these and other general health and safety requirements can be found in the 'References' and 'Further reading' sections.

8 Where the word 'must' has been used it is intended to mean a reference to a legal obligation. A summary of the main legal provisions is in Appendix 1.

Implementation of this guidance to devices designed before 1997

9 Reports of design review may not be available or needed for older attractions (those designed before 1997) whose design has been proved by maturity and can be demonstrated in a maturity design risk assessment. While in principle the hard evidence of an attraction's operational history may be an acceptable basis for proving a design, much depends on the history of modifications. Whether a design review is needed or not depends on the controller's assessment of risk, aided by advice from an inspection body. Guidance on the contents of a maturity design risk assessment is in Section D, paragraphs 76–77 and Appendix 2.

Section A
The system for safety of attractions

Table 1 The system for safety of attractions

Steps	Checks	Description
Design		By competent designers with knowledge of the relevant standards (see Section C).
	Design review*	Appraisal of a design (and any safety-critical modification) to check the adequacy of a design specification and the validity of the assumptions on which it is based (see Section D).
Manufacture		To the design specification.
	Assessment of conformity to design*	A check to confirm that a device is constructed to the reviewed design specification (see Section D).
	Initial test*	A test to check that the device operates safely in accordance with the reviewed design specification and the instructions in the operations manual. This test should be carried out by, or on behalf of, the manufacturer, supplier or importer and witnessed by an inspection body.*
Provision of an operations manual		Provision of adequate information required for the safe operation and maintenance of the device (see Appendix 3).
Device operation		Carried out by competent persons, suitably trained in normal operation and emergency procedures and in accordance with the operations manual and risk assessment.
Ongoing device integrity		By a series of checks, maintenance and inspection.
	Maintenance	The procedures carried out by competent persons necessary to ensure that a device is kept in an efficient state, efficient working order and in good repair.
	Daily check	Carried out by competent persons before the device is opened for use (see Section F).
	Periodic check	Carried out by competent persons in accordance with the manufacturer's specifications and any additional requirements required by modifications to the device, and/or the findings of the design review or risk assessment.
	In-service annual inspection*	The procedure necessary for a registered inspection body to decide whether an amusement device may continue to be operated for a specified period of time (see Section D).

* Carried out by an inspection body registered with ADIPS to undertake that category of work.

Table 2 Recommended actions for different types of attractions

Type of attraction	Ride?	Amusement device?	Stall?	ACTIONS: Design review and assessment of conformity to design?	Initial test?	In-service annual inspection?	Daily check?	Other important safety issues and comments
Arcade	No	Yes	No	Yes[a]	Yes[a]	Yes[a]	Yes	(a) Non-permanent structures only. For fire precautions see Appendix 6. Check electrical equipment at least annually.
Boxing booth	No	Yes	No	Yes	Yes	Yes	Yes	May be 'tented structure' (see Appendix 6).
Cableway	Yes	Yes	No	Yes	Yes	Yes	Yes	The Cableway Installations Regulations 2004[1] do not apply to cableway installations (on site or mobile) in fairgrounds or amusement parks that are designed for leisure purposes and not as a means of transport. They do contain advice which may be useful.
Coin-operated amusement device	Yes	Yes	No	No[b]	Yes	Yes	See note in paragraph 191	(b) Devices outside the definition given in the Glossary require the full range of pre-use and in-service inspections. Local-authority-enforced when used outside fairgrounds and amusement parks.
Coin-operated game	No	No	Yes	No	No	No[c]	Advised to check plugs and leads	(c) Periodic inspection of electrical equipment.
Funhouse – with moving floors and slides etc	Yes	Yes	No	Yes	Yes	Yes	Yes	May be 'tented structure' (see Appendix 6).
Guns/ crossbows	No	No	No	No	No	Strip down by specialist advised	Yes	Firearms legislation may apply.
Hall of mirrors etc	No	Yes	No	As arcade above	As arcade above	As arcade above	As arcade above	As arcade above.

Table 2 Recommended actions for different types of attractions

				ACTIONS				
Type of attraction	**Ride?**	**Amusement device?**	**Stall?**	**Design review and assessment of conformity to design?**	**Initial test?**	**In-service annual inspection?**	**Daily check?**	**Other important safety issues and comments**
Hoopla stall	No	No	Yes	No	No	No[d]	Yes	(d) Periodic inspection of electrical equipment.
Hot dog or candy floss stall	No	No	Yes	No	No	No[e]	Yes	(e) Periodic inspection of electrical equipment. Food safety legislation applies. See Appendix 6 for advice on gas safety.
Inflatable (bouncy)	Yes	Yes	No	Yes	Yes	Yes	Yes	Supervision.
Other inflatable (not used for bouncing or sliding)	No	Yes	No	Advised for safety-critical components	See design review	See design review	Yes	Supervision.
Pneumatic or air-supported structure	No	Yes	No	Yes	Yes	Yes	Yes	For fire precautions see Appendix 6.
Ride, adult or juvenile	Yes	Yes	No	Yes	Yes	Yes	Yes	Passenger containment and supervision.
Road train	Yes	Yes	No	Yes	Yes	Yes	Yes	Driving licence recommended, training and supervision.
Safety-critical parts of theming (may be part of an attraction or general site theming)	No	No	No	Yes[f]	Yes[f]	Yes[f]	Yes[f]	(f) A high degree of care should be applied to the safety-critical parts of any theming which could cause serious personal injury if they failed.

Table 2 Recommended actions for different types of attractions

				ACTIONS				
Type of attraction	**Ride?**	**Amusement device?**	**Stall?**	**Design review and assessment of conformity to design?**	**Initial test?**	**In-service annual inspection?**	**Daily check?**	**Other important safety issues and comments**
Self-drive, eg model cars, dodgems, karts	Yes	Yes	No	Yes	Yes	Yes	Yes	HSG200 *Go-karts: Guidance for safe operation and use*[2] provides useful information.
Shooting gallery (hazardous projectiles)	No	Yes	No	Yes	No	No[(g)]	Yes	Firearms legislation may apply. (g) Periodic inspection of electrical equipment.
Shooting gallery (non-hazardous projectiles)	No	No	Yes	No	No	No[(h)]	Yes	(h) Periodic inspection of electrical equipment.
Slide	Yes	Yes	No	Yes	Yes	Yes	Yes	Supervision.
Walk-through house, eg haunted house	No	Yes	No	Yes	Yes	Yes	Yes	May be 'tented structure' (see Appendix 6).
Wall of death/ Globe of death	No	Yes	No	Yes	Yes	Yes	Yes	Important to maintain structural integrity.

Section B
Managing health and safety

Identify what needs to be done

10 Safety doesn't just happen. It requires everybody's commitment and willingness to work in an organised way to achieve good standards. The most important steps to managing health and safety are the policy, organisation, planning, monitoring, auditing and reviewing. These concepts are recognised in all sections of this book.

Planning

11 The planning process should identify the hazards, assess the risks and help determine what control measures are required. Sections C to G indicate how to effectively manage safety.

Risk assessment

12 Most accidents happen because simple precautions are not taken. Risk assessment involves looking at what can go wrong, the likelihood of it going wrong and identifying what you can to do to prevent it – it is often about applying common sense in a logical way. See HSE's leaflet INDG163(rev2) *Five steps to risk assessment*.[3]

13 Consider both hazard and risk in a risk assessment:

- Hazard – anything that can cause someone harm.
- Risk – the chance that someone could be harmed and how serious the harm could be. The greater the chance and seriousness of injury, the higher the risk.

14 Risk assessment can be broken down into five steps:

Step 1 Identify the hazards

15 Use the following to work out how people could be harmed:

- your own or others' experience, information from trade associations, advice from HSE, fire authorities or published guidance from the manufacturers;
- technical information from designers and inspection bodies;
- your own enquiries and inspection;
- information from your workers, contractors and other people.

Step 2 Decide who might be harmed and how

16 For each hazard, you need to be clear about who might be harmed – this will help you decide the best way to manage the risk. Although public safety is of prime importance, workers and others, such as members of a ride owner's family, may also be injured.

Step 3 Evaluate the risks and decide on precautions

17 The risk assessment process may identify additional measures that need to be implemented to adequately control the risks. It is important that these measures are put in place. Evaluate the risks and decide whether the existing precautions are adequate or whether more should be done. Control measures need to be appropriate to the level of risk. The greater the risk, the greater the standard of control required. The public expects a high standard of safety, particularly when the risks are outside their control, eg risks from machinery. However, many will accept the risk of a minor bump (eg on the dodgems) as part of the fun.

Step 4 Record your findings and implement them

18 If you employ more than five people you must record the significant findings of your risk assessment and the measures you are taking to control risks. Although not law, the industry associations strongly recommend that you do this even if you have fewer than five staff. Recording these details will help show that you are running your business safely.

Step 5 Review your risk assessment and update it if necessary

19 Regularly review your assessment and revise it if necessary in the light of experience or any changes such as:

- accident/incident history, eg of any similar devices;
- renovation;
- modifications, including physical, procedural or software modifications.

Who should do a risk assessment?

20 Every employer and self-employed person must assess the risks to workers and others who will be affected by their work or business. Dutyholders in the fairground and amusement park industry will be involved in a range of risk assessments. For example:

- Designers need to:
  - identify how the public or workers might be injured, including risks arising from the need to inspect and maintain the ride, as well as from its use as an attraction and emergency situations;
  - determine possible effects of 'foreseeable misuse' (see paragraph 23 for a definition) by the public, controllers or operators.
- Manufacturers need to:
  - identify the risks to their employees and others during the manufacturing process.
- Installers need to:
  - identify the risks to their employees and others during the installation process, such as risks from working at height, manual handling, electricity etc.
- Organisers needs to:
  - assess site risks, for example, access, transport, limitations of space, overhead power lines;
  - produce a site layout which will minimise the risks;
  - identify any planning, equipment, information and training needed to deal with emergencies.
- Controllers need to:
  - assess the risks from transporting, assembling, maintaining and using the attraction.

21 In some cases the duties will overlap, for example if someone both designs and manufacturers an attraction. If this is the case, dutyholders need to:

- identify any control measures, precautions, information, instructions and training needed to make sure that all jobs are done safely;
- review their assessment, where relevant, in the case of changes in design, manufacturing process, modifications, operating conditions, operational experience etc.

What is 'reasonably practicable'?

22 Many of the requirements of health and safety legislation require you to take 'reasonably practicable' steps and precautions to manage risks. The term 'So far as is reasonably practicable' means you have to take action to control health and safety risks except where the cost (in terms of time and effort as well as money) of doing so is grossly disproportionate to the reduction in the risk. You can work this out for yourself, or you can apply accepted good practice. The guidance in this book is supported by the trade associations as being good practice.

What is 'foreseeable misuse'?

23 The concept of 'reasonably foreseeable' excludes the irrational (eg drying the cat in the microwave). The foreseeability of the danger includes considering the likelihood of the combination of circumstances that there would need to be for the potential of harm to be realised. You will need to consider foreseeable situations in which the passenger's expected actions, as a result of not being able to fully perceive the danger or as a result of something unexpected happening, may expose them to an increased risk.

24 The term foreseeable misuse is not intended to include improbable or outrageous misuse. It could include:

- a ride being loaded out of balance;
- trying to start a ride before the passenger restraints have been closed;
- passengers trying to leave before a riding cycle is finished.

25 It is important to consider such misuses early on so that they can be taken into account at the design stage. Some foreseeable misuses may be preventable by design features such as interlocks. The designer may need to give advice for inclusion in the operations manual, for example in the case of out-of-balance loading the designer should:

- decide what out-of-balance loading is foreseeable;
- make sure that the ride design has considered the effects of such loading;
- give advice on safe loading of the ride.

Consultation with employees

26 Employers must consult all employees on health and safety issues 'in good time' on:

- new measures;
- appointing competent persons to advise on health and safety;
- health and safety information;
- health and safety training;
- new technologies.

27 Where trade unions are recognised, this must be done through the representatives they appoint. Other employees must also be consulted, either directly or via their elected representatives.

Section C
Designing and manufacturing an attraction

Designers

28 Amusement devices can range from relatively simple designs such as small juvenile rides, to large, adult rides of considerable complexity. It is important for the safety of the public who use them, and the operators who work on them that safety is considered adequately at the design stage.

29 As a designer of an amusement device you should ensure that it will be safe when it is being:

- assembled, dismantled, transported and installed;
- operated, cleaned, maintained, inspected and tested;
- used by the public.

30 You should specify the conditions in which the amusement device is expected to operate. This should include any limitations on use. You should also ensure the design is:

- supported and proved by any testing, examination and research needed to demonstrate that the device will be safe when used as intended;
- sufficiently detailed to ensure that it can be built, operated, maintained and inspected safely (including any special requirements for installation);
- validated as a whole, which is especially important when parts of the device are made by different manufacturers.

31 You should make sure that all the design work is properly carried out in accordance with relevant standards, is thoroughly documented and that all necessary quality assurance relating to the design is carried out.

32 You should make recommendations to the manufacturer/supplier, as appropriate, for items to be included in a commissioning schedule to ensure that the amusement device is properly commissioned before first being put into use.

33 You should also provide appropriate input to operating instructions, inspection and maintenance schedules etc, necessary for safe operation of the amusement device so that they can be included in the operations manual. This documentation should be in a language that is understandable by the people to whom the amusement device is being supplied.

Design risk assessment (DRA)

34 The fairground industry publication *Safety of amusement devices: Design*[4] defines a design risk assessment as: 'the process of assessing the hazards that an amusement device might pose, the likelihood of those hazards causing a risk and the control measures that are necessary to control those risks adequately'.

35 As a fundamental element of the design process, you should assess all the risks associated with the design, as well as those risks arising out of the activities specified in paragraph 29 and record this in the DRA. It should be used to help specify the safety functions of the amusement device.

When more than one designer is involved

36 The overall design of an amusement device may involve contributions from a number of people. For example, there may be separate designers for passenger cars, passenger restraints, track, control systems etc. It is important that the process of producing the overall design is co-ordinated and managed effectively to ensure that all safety-related aspects are considered and combined effectively.

37 For fairground equipment designed in Great Britain (GB) the responsibility for co-ordinating the design work lies with the person responsible for the overall design of the device.

38 Where the fairground equipment has been designed outside GB, the supplier or importer assumes the responsibility for ensuring the amusement device is safe to operate. In such cases they should take all reasonable steps to ensure that the advice in paragraphs 29–33 has been followed.

Pre-use inspections

39 Before an amusement device is used for the first time, the safety-related features of the design should be checked through a process of pre-use inspections, using an appropriately registered inspection body (see Section D paragraphs 83–122 for more information on pre-use inspections).

Designers and the design review process

40 One of the pre-use inspections is the process of design review. This should preferably be carried out before the device is manufactured. The designer should make all information required by the design review body available, as the device will not be able to operate without it.

41 Where you know that an inspection body has been appointed to carry out a design review, you are encouraged to consult them as early as possible in the design process. This is so that any possible design problems can be designed out at an early stage rather than at the end of the process, where even a seemingly minor requirement might be extremely difficult or time-consuming to implement.

Modifying an existing design

42 If an existing device is modified, the controller of the device should select a competent person to co-ordinate the modification process. This is to ensure that all the safety-related aspects of the modification are considered.

43 Designers who become aware of a feature of their design that might lead to danger should:

- take all reasonable steps to ensure that controllers using that version of the device are made aware of this;
- tell controllers about details of any modifications that are required and any time-scale that applies.

44 The controller should ensure that the safety-critical aspects of a modification to an existing design are subject to the three pre-use inspections. See paragraphs 182–183 for details of what constitutes a safety-critical modification and paragraphs 83–122 for details of pre-use inspections.

45 Any person within the supply process who becomes aware of a design deficiency that might lead to danger should take all reasonable steps to ensure that others known to be in the supply chain and any controllers using that version of the device are provided with necessary information to avoid failure of the device.

Manufacturers

46 During the manufacturing process you as a manufacturer should ensure:

- that every device fully meets the design specification in terms of materials, material properties, dimensions, quality and manufacturing standards etc; and
- that parts which are not readily identifiable for correct assembly are clearly marked in a manner which will avoid errors in assembly; and
- that those constructing the device (eg welders, electrical technicians etc), including any subcontractors, are suitably qualified and competent to do so.

47 Where you use subcontractors for part of the manufacturing process, you should specify the following:

- the name of the individual or organisation which has the overall co-ordinating role for manufacture (either yourself or someone appointed on your behalf); and
- the extent and limits of all contractor’s duties and responsibilities; and
- the expected criteria for quality assurance and quality control.

Quality assurance

48 You should make sure that:

- the device is manufactured to the design specification and that all components and materials used are of the correct quality; and
- all aspects of manufacture are controlled by measures designed to produce a consistent and high standard of quality, eg by reference to established quality assurance procedures;
- people manufacturing the device are competent; and
- it is manufactured to the appropriate standards.

Control systems

49 Where the device has safety functions that make use of one or more electrical, electronic, or programmable electronic safety-related control systems, make sure that the system, including any software that may have a safety function, is designed, developed and quality assured using the principles set out in relevant standards.

Non-destructive testing (NDT)

50 You should also check that any NDT required during the manufacturing process has been done. It is good practice to keep the records of such tests for the lifetime of the device. You should add any relevant pre-use NDT reports to the operations manual; this is because if flaws are subsequently found by NDT, it will not be known whether these flaws have arisen during operation. See Appendix 5 for further details.

Commissioning schedules and initial test

51 You should ensure that a written commissioning schedule is in place that can be used by those people who are expected to install and put amusement devices into use.

52 It should confirm that the device has been manufactured and installed so that all operational and safety systems are functioning correctly. It should also list the tests that will need to be carried out during initial test. See Section D paragraphs 110–122 for more information on the initial test.

53 The commissioning process in itself is not a substitute for an adequate initial test to be witnessed by the inspection body. To ensure the installation process is managed effectively, the commissioning process and initial test should be seen as separate exercises and clearly identified as such.

Installing an amusement device as a fixed structure

54 This section refers to the assembly of a device that is designed as a fixed structure, and not as a mobile structure which is designed to be frequently erected and dismantled. For a new fixed structure, installation can be part of the manufacturing or supply process (depending on the design of the device and the terms of the contract). Installation may also involve more than one manufacturer and may be wholly or only partly under the controller’s control.

55 The parties involved will need to co-operate and co-ordinate to ensure they are clear as to who is responsible for what and at which stage. This should be confirmed in writing before any work begins, and any modifications to the plan confirmed in writing to all interested parties.

56 If a device is installed as a fixed structure, but later dismantled and reinstalled, this should be considered as a modification. However, as long as no changes to the design have been made, a design review may not be necessary for the structure, but will normally be required for the design of the foundations unless the ground conditions are identical. The extent of the design review is a decision to be reached by a design review inspection body.

57 An initial test will still be required to confirm that the device has been reinstalled correctly and that items such as theming have been added correctly. If any theming is involved, then this should be included in all the pre-use inspections if it can affect the safety of the amusement device.

Converting a mobile amusement device to a static fixed device

58 There are times when a device that was originally designed for mobile use will be used as a fixed structure. The controller should ensure that any additional factors, such as extra theming or ground conditions, do not introduce risks (eg by compromising the safety envelope of the amusement device).

59 If the process of dismantling the amusement device and its subsequent assembly as a fixed device did not involve intrusive processes or any changes that may affect the safety of the device, then the necessity for pre-use inspection may be limited to an initial test. The scope of the initial test will depend on any risks associated with items added to the device that would not normally be associated with mobile devices.

60 If safety-critical modifications have been made, the device will need to have the full range of pre-use inspections carried out before it is brought back into use.

Importing an amusement device

61 You are an importer if you bring a device into the country either temporarily or permanently. If you buy a foreign device through an agent who is permanently resident in Britain, the agent is normally the importer.

62 You are responsible for ensuring that the pre-use inspections (design review, assessment of conformity to design and initial test) are carried out and that the designer and manufacturer have followed the information in this book. You can do this by checking that the operations manual contains the necessary reports on the pre-use inspections.

63 The device should not be used unless these pre-use inspections have been carried out, and the inspection body verifying the inspection reports has confirmed in writing it is satisfied that the device is safe to be used.

64 It is recommended that in purchase contracts for new devices you should request that designers, manufacturers and importers follow the appropriate guidance in this book and in the publication *Safety of amusement devices: Design*.[4]

65 You should take care to check that the documentation you receive follows the requirements of ADIPS pre-use inspections. Differences in methodology, practice, procedures and certification requirements between countries can lead to different interpretations of what is required, for example:

- use of design criteria inappropriate for Britain, eg wind loading;
- incomplete review, eg with no, or inadequate, attention to control systems or passenger-containment systems;
- false assumptions, eg that a component or a safety-control system will never fail or that it will fail safe.

Supplying an amusement device

66 You become a supplier if you sell (or hire out) any device, new or second-hand. Make sure you do everything necessary to check that the designer, manufacturer and importer, as appropriate, have complied with their legal requirements and have followed the advice in this guidance.

67 You can do this by checking that the operations manual contains the necessary reports on the pre-use inspections: design review, assessment of conformity to design and initial test. If these have not been done, you will need to take steps to have these completed before the device is first used.

68 You must provide the controller with all the information necessary for safe use, before the device is first used. You should include the reports of pre-use inspections, and any modifications stemming from them.

69 If you intend to hire a device it should have a current Declaration of Operational Compliance (DOC) (for inflatable devices a DOC issued under the ADIPS system or a safety certificate issued under the PIPA scheme). This information should be included in the operations manual. It should be in English (and the language of the controller, if different) and be adequate for effective safe use, maintenance and inspection of the device.

Section D
Inspecting an amusement device

Inspection and testing

70 This section provides guidance on the procedures that are in place to ensure that amusement devices are checked for safety before they are first used, and on the periodic annual in-service inspection required to assess their ability to operate safely throughout their working life. See Section F for guidance on maintaining and carrying out the daily checks which are required to operate a device safely.

71 There are currently three agreed schemes in this industry for the inspection and testing of amusement devices:

- The Amusement Devices Inspection Procedures Scheme (ADIPS) involves a series of pre-use and in-service inspections, and applies to all fairground rides, amusement devices and inflatable amusement devices. The amusement industry trade associations recognise this as the scheme for the pre-use inspection, in-service annual inspection and certification of all amusement devices. It is administered by ADIPS Ltd.
- Within ADIPS, the pre-use and in-service inspections of all coin-operated amusement devices that do not fall under the main ADIPS scheme. This is administered by the British Amusement Catering Trade Association (BACTA) on behalf of ADIPS.
- The PIPA scheme is administered by the Performance Textiles Association (PERTEXA). This scheme is also recognised as being appropriate for the pre-use and in-service inspection and certification of inflatable amusement devices.*

* PIPA is supported by the inflatable industry associations (IPMA, AIMODS, BIHA, NAIH) and was developed in consultation with HSE. Design, conformity and initial test are certified by a uniquely numbered PIPA tag that is permanently attached to the unit, as well as a yearly renewable inspection certificate. Further information can be found on the PIPA website: www.pipa.org.uk.

Amusement Devices Inspection Procedures Scheme (ADIPS)

72 ADIPS covers:

- types of inspection required for amusement devices;
- registration and administrative control of inspection bodies;
- documentation required by amusement device operators;
- inspections required for coin-operated passenger-carrying amusement devices and liaison with BACTA.

Types of inspection covered in ADIPS

73 There are four types of inspection within ADIPS that fall into two categories: pre-use inspections and the in-service annual inspection.

Pre-use inspections

74 These should be carried out before an amusement device is used for the first time in GB, or after any safety-critical modifications to an existing amusement device. These are:

- Design review (paragraphs 85–103).
- Assessment of conformity to design (paragraphs 104–109).
- Initial test (paragraphs 110–122).

In-service annual inspection

75 This should be carried out at least once every 12 months (see paragraphs 124–134). Note that an inspection body may require a further examination at a specified shorter period.

Maturity risk assessment (MRA)

76 When ADIPS was introduced in 1997, it was recognised that there would be devices in use that had not been subject to pre-use inspections and did not have complete design documentation, but that were, however, well-designed and maintained. An arrangement was therefore reached to allow such devices to continue to operate. The controllers of these devices were given until 2004 to prepare an MRA that could be used to demonstrate safety through maturity of a device. This only applied to devices that had operated in GB before 1997.

77 It is accepted that there will be a number of older amusement devices operating that now have an MRA instead of the ADIPS pre-use inspections. To help assess the adequacy of these MRAs, guidance on the background to the MRA process, and information on what should be included in one is outlined in Appendix 2. This information may be used by both inspection bodies and HSE inspectors to determine the adequacy of the MRA.

Register of inspection bodies (IBs)

78 The amusement industry trade associations have agreed that only inspection bodies registered with ADIPS should carry out inspection and certification of amusement devices. An inspection body may be registered for any or all of the types of inspection. They should only work within the scope of their registration. For example, bodies only registered to carry out in-service annual inspection should not carry out design reviews etc.

79 ADIPS contains a service quality schedule (SQS) for each type of inspection, identifying the qualifications, experience and procedures necessary for an inspection body to be registered with the scheme. The SQSs are currently based on the requirements of ISO 17020.[5] The registration procedure requires all inspection bodies to compile and maintain a quality file containing details of their qualifications, experience and other competencies, as required by the SQSs.

Administration of ADIPS

80 ADIPS Ltd and BACTA administer the scheme:

- ADIPs deals with the inspection bodies who carry out the four types of inspections needed on amusement devices. They have prepared a series of forms (available from ADIPs Ltd) that should be used by inspection bodies. Only inspection bodies that are competent for the type of work that they carry out may be registered with ADIPS.
- BACTA administer the scheme only in respect of qualifying coin-operated, passenger-carrying amusement devices. In this scheme only the initial test and in-service annual inspection are required.

Independence of inspection bodies

81 Inspection bodies carrying out pre-use inspections should be able to demonstrate independence from the design, manufacture, supply and importation process of the device they are inspecting, both for new devices and for safety-critical design modifications to existing devices. This is to avoid any potential conflict of interest where the independence of their work might be compromised. In the BACTA scheme the inspection body need not be independent of the operating or manufacturing company.

82 Where specialist expertise is required during in-service inspection, it may be necessary to use a person who is not independent of the supply process. For example, it may be appropriate in some instances to use the manufacturer of a specialist component to give advice on its fitness for further use. The competence of any specialist used is the responsibility of the person who appointed or contracted them. Any use of such specialists should be with the agreement of the appointed inspection body.

The pre-use inspection process

83 The controller of an amusement device is responsible for ensuring that the three pre-use inspections are carried out before it is brought into operational service, either for the first time following its manufacture or importation, or after any safety-critical modification. The controller may appoint an inspection body to take overall responsibility for arranging the work, confirming the completion of the pre-use process and issuing the Declaration of Operational Compliance (DOC). This inspection body is known as the Appointed Inspection Body (AIB). The AIB may collate the work of others to complete the process and issue the DOC, or they may carry out some or all of the work themselves, depending on the circumstances and complexity of the task. Where only one body is involved it will automatically become the AIB.

84 It is important that the AIB confirms before issuing the DOC that any requirements for further procedures and testing outlined in the design review have been satisfactorily completed.

Design review

85 Design review is the first of the pre-use inspection procedures. Its purpose is for an independent and competent inspection body to assess a design prepared for a device, and conclude whether the designer has adequately addressed all issues that may affect the safety of the device that will be relevant throughout its intended operational life. Only inspection bodies registered with ADIPS to carry out design reviews should carry them out.

When is a design review needed?

86 A design review should be carried out for any amusement device supplied or imported into GB before it is used for the first time. It is also needed for any device that has had a safety-critical modification. Where a design review is assessing a modification to a device, it can be limited to the modification and any other safety-critical parts of the device affected by it.

Application of a design review

87 It is essential that a design review clearly identifies the precise model number or design version of the device. If the designer or importer has not specified a design version number, the inspection body should identify the amusement device to which the review applies. This identification should appear on all documentation.

88 The design of a type of amusement device may vary over time as the designers and manufacturers change and update the original specification. In some cases modifications to the design may be minor, in other cases substantial. Changes may or may not be safety critical. It cannot therefore be assumed that, simply because a device bears a physical resemblance to an earlier model, it is the same in every regard. If a design is modified in any way that affects safety, a further design review will be needed.

89 If a design review is carried out and intended to apply to a series of identical devices, then this should be clearly stated on the front sheet. In this case the other pre-use inspections will still be required for each individual device. Where a new model of an existing ride design is put forward for design review, the inspection body may be unable to confirm that the existing design review is valid for the new model without further work being done. For example the design drawings referenced in the original design review will need to be available to the inspection body so they can check that the design of the new device is identical to the one previously reviewed.

90 If anyone intends to buy, import or supply a new device and an existing design review (for example, a design review carried out for an earlier model of a device) is provided as evidence that the design of the new device is safe, written confirmation should be obtained from the original design review inspection body, that their design review is valid for the new device and applies in all respects to the new device that is now being brought into use.

91 The other pre-use inspections, assessment of conformity and initial test that are designed to ensure the device is as reviewed will still be required for the new device.

Managing design review

92 When a design review is commissioned, an inspection body should be selected by the person commissioning the work to take overall responsibility for co-ordinating the design review process. This inspection body may subcontract to, and/or collate the reports issued by, other registered inspection bodies where such bodies have been appointed by other parties (eg designer, manufacturer or controller) to carry out discrete parts of the overall review.

93 The co-ordinating inspection body is responsible for ensuring the competence of anyone subcontracted by them who is not registered with ADIPS. They are not responsible for the quality of reports carried out by other registered inspection bodies who bear that responsibility themselves.

Contents of a design review

94 The design review should include (but not be limited to) the adequacy of the following:

- the design calculations;
- the design documents, which should be consistent with appropriate standards, specifications, guidelines and industry practice;
- details of any non-evidence-based assumptions, particularly those on which any calculations are based (eg fatigue life);
- the design and operation of any control system (electrical, electronic or other, programmable or otherwise);
- an assessment of the structural/mechanical safety of the amusement device;
- the suitability of the containment system (and the adequacy of any passenger restraints included as part of this system);
- the operating instructions, which should be clear, complete and sufficiently detailed;
- the inspection and maintenance schedules, including the NDT schedule and that they are sufficiently detailed.

95 The co-ordinating inspection body should confirm the extent of the review. Some modifications may require only limited review, but a change to the seating capacity, for example, might require the whole device to be reassessed.

96 The inspection body issuing the DOC should ensure that the following has been done:

- confirm that the steps in paragraph 94 have been completed;
- confirm that the design of all relevant component parts (eg mechanical, structural, hydraulic, control system, electrical, electronic, ergonomic, containment etc) of the device have been reviewed by competent inspection bodies and their findings presented.

When is a design review complete?

97 A design review should reach one of four conclusions:

- the device will be safe if built and operated and maintained to the design that has been reviewed; or
- deficiencies in the design have been identified, however, the device is considered to be safe to operate **where specified written operating, inspection and/or maintenance arrangements are in place** to address those deficiencies (eg limitations in operating conditions such as reduced numbers of cars, reduced speed, specified inspections of critical parts etc); or
- deficiencies in the design have been identified, however, the device is considered to be safe to operate for a limited number of cycles. In this case the design review **must be limited, either by date or by number of completed ride cycles**, and after it expires:
  - either a further review must be carried out to determine whether the device is safe to operate and what conditions of operation, maintenance and/or inspection are required; or
  - written confirmation has been received from the design review body that all outstanding issues have been satisfactorily resolved;
- the design of the device is deficient to the extent that the device cannot be safely brought into service. In such cases the design review should state the reasons why. This should be communicated to the person who commissioned the review as soon as possible.

Deficiencies in the design

98 Where the design review identifies deficiencies or where there is inadequate information available to allow a design review to be carried out satisfactorily, this should be brought to the attention of the person who commissioned the design review, who should take appropriate action to rectify the deficiency.

99 Where any re-design has been carried out, it should be subjected to design review, to the extent determined by the inspection body.

100 A design review may produce findings that have implications for the safety of other devices. The controller and the design review body are advised to contact their trade association and/or the ADIPS bureau in such cases.

Completing the report of design review

101 As a minimum the report of design review should contain the following:

- information on the scope of the design review, eg whether it deals with a part (structural, electrical etc) or all of the design;
- a means of identifying the specific device including any model numbers;
- a list of the drawings, with drawing dates and revision numbers, calculations and information reviewed;
- the categories in paragraph 94 which apply to the design being reviewed;
- any measures that are required for safe operation;
- any extra information identified by the review that is required for the future inspection, operation and maintenance of the device;
- any time/cycle limitations;
- items that require further consideration at either the ACD or initial test stages.

102 The report of design review is not a substitute for the information that should be provided by the manufacturer, designer, importer or supplier which is required for the safe operation, inspection and maintenance of the device. This information should be in the operations manual (see Appendix 3 for further details).

103 Once the design has been reviewed, some safety-related matters may still need to be proved by testing or other procedures. Where this is the case, the inspection body should state this in the design review. They should include details of any further information and test results that are needed by them to allow the review to be completed. The design review will not be complete until any further work specified has been completed.

Assessment of conformity to design (ACD)

104 Assessment of conformity to design (ACD) is the second of the pre-use inspections. Its purpose is for an independent and competent inspection body to check that the safety-critical aspects of a manufactured device conform to the reviewed design.

105 The ACD for a device coming into use for the first time in GB should cover the entire device, including structural, mechanical, electrical, electronic, hydraulic and pneumatic assemblies. An assessment of a safety-critical modification, however, may only need to cover the parts affected.

106 As with the process of design review, it may be that more than one inspection body will be involved in checking the assessment of conformity to design of a device, especially if the device is large or complex. The person who commissions an ACD should therefore appoint an inspection body to take overall responsibility for co-ordinating the process. This inspection body may subcontract to, and/or collate the reports issued by, other registered inspection bodies where such bodies have been appointed by other parties (eg designer, manufacturer or controller).

107 The ACD should confirm that the design review corresponds specifically to the device being assessed. The process should involve using the drawings and information referenced in the design review. Examples of areas that may need to be considered are:

- critical structural dimensions;
- mass of components which could affect safety;
- conformity of materials to the design specification;
- conformity of electrical, hydraulic and pneumatic assemblies to the reviewed design.

108 The methods used may be physical and visual assessment and/or by considering quality assurance (QA) documentation from the manufacturing process. Sampling may be appropriate in some cases.

Issuing the certificate of assessment of conformity

109 At the completion of the ACD process, the inspection body should issue a report of assessment of conformity to design. This should be submitted to the AIB and should contain the basic information recommended in paragraph 107 and clearly specify:

- what has been assessed; and
- any parts of the device which do not conform to the specification. It is recommended that this information should be passed to the person who commissioned the report and the manufacturer, where different.

Initial test

110 The initial test is the third of the pre-use inspections. The purpose of this inspection is to have an independent and competent inspection body check that the safety-critical aspects of a device function as intended. An initial test is needed at the following times:

- before first use of any device in GB;
- before re-use after any safety-critical modification;
- before first use of any device installed at a fixed site (see Section C, paragraphs 54–57).

111 The controller of the device is responsible for ensuring that the initial test is carried out. It is normally carried out by or on behalf of the designer, manufacturer, importer, or supplier in accordance with a prepared schedule, and verified by the inspection body. The inspection body should ensure that all relevant tests have been carried out satisfactorily before issuing a report of initial test.

112 Commissioning tests may not substitute for a properly conducted initial test. However, information from such tests may be submitted to the inspection body witnessing the test as evidence of the device's performance under particular conditions. The inspection body will decide whether the evidence is suitable to include as part of the tests required to issue a satisfactory report of initial test.

113 The initial test programme should take into account any recommendations for checks and tests included in the reports of design review.

114 All documentation supplied for the purposes of the initial test should be in English. It would not be possible to conduct an adequate initial test if the documentation were in a foreign language.

115 The initial test is likely to be made up of a number of different tests that measure and record performance, rather than just checks on the function of the controls. For example, when a stop control is tested, it may be important to know how long the device takes to stop and that functionally it does stop within prescribed limits. This will allow the controller to detect any later deterioration in performance.

116 The device should be tested against its foreseeable operating conditions. For example, if a device is manufactured with an operational capability of being run by the operator at a rotational speed of 25 rpm, it should be tested at that speed to give a true test of its possible performance.

117 Using documentation relating to tests done by others is acceptable if reasonable steps have been taken to verify that the tests were relevant, the procedures used were appropriate and the results reliable. These reports need to be added to the report of initial test. Where previous tests are accepted, functional testing of the device under both normal and foreseeable emergency conditions still needs to be witnessed by the inspection body.

Managing initial test

118 The initial test should include, where relevant, but not be limited to:

- an assessment of the stability of the device including when foreseeably unbalanced;
- checking the safety-critical elements of safety envelopes;
- checks to make sure that switches, valves, variable controllers (eg pressure regulators), overload protection (eg pressure-relief valves) etc are properly set and, where appropriate, locked off, and settings recorded;
- observations and measurements of the performance of the device under normal loading and foreseeable unbalanced loading in all the configurations permitted in the operations manual;
- measurements of speeds, accelerations and forces **up to the maximum design capability** of the amusement device to check the validity of the design calculations;
- tests of the function and performance of safety-critical systems in normal operation and under foreseeable fault and emergency conditions;
- confirming the availability of an operations manual in the language of the controller.

119 Test loads should be of an appropriate size and shape, for example a sandbag strapped to a seat might be adequate to test structural members supporting a passenger unit, but might not be suitable to test the effectiveness of a passenger restraint.

120 When the initial test is complete, the inspection body should discuss the results with the designer, controller and co-ordinating design review inspection body and document any unsatisfactory results, damage or failure. The inspection body should document what repeat testing may be needed after any remedial action that has been found to be necessary has been completed.

121 A report of initial test needs to be issued to the person who has commissioned the report for subsequent inclusion in the operations manual. A report of initial test should not be issued unless the inspection body has witnessed and verified that at the time and place of test the device has performed safely.

Issuing a report of initial test

122 The inspection body needs to prepare a report for inclusion in the operations manual. A satisfactory report should be based on the schedule provided by the designer/manufacturer and verified in the design review. The following should be included where relevant:

- the loads used and results obtained (as the reference for future tests);
- details of the relevant testing done by the manufacturer and the results obtained;
- copies of inspection reports and tests done by others;
- details of the weather conditions at the time of the test, if relevant;
- any limitations as to use identified during the initial test;
- any aspects of performance identified during the initial test that the controller should monitor and details of how that work should be done;
- that a initial test has been witnessed and the device performs according to requirements of the initial test schedule.

Completion of the pre-use inspections and issue of the Declaration of Operational Compliance (DOC)

123 A DOC can be issued by the AIB when the inspection bodies carrying out each of the pre-use inspections have confirmed in writing that these inspections have been satisfactorily completed. The DOC should be issued with an expiry date subject to any conditions imposed as a result of the findings of the pre-use inspections, but in any case should be no longer than 12 months.

In-service annual inspection

124 In-service annual inspection is the fourth of the package of safety inspections for devices operating in GB. Its purpose is for an independent and competent inspection body or bodies to check on the fitness of an amusement device for continued further use during its operational life. It is a check on the safety-critical components of an amusement device to ensure that they have not deteriorated to an extent liable to cause danger.

125 A successful in-service annual inspection will verify that the device is fit to be used for a specified period. It does not remove the duty on the controller of a device to ensure that the device is adequately maintained, nor does it duplicate the pre-use inspection procedure.

Managing in-service annual inspection

126 The controller of an amusement device should choose an inspection body to act as the AIB. It is the role of the AIB to issue the DOC when the inspection has been satisfactorily completed. Where only one inspection body is involved it will automatically become the AIB.

127 There may be a number of different inspection bodies carrying out inspections and tests of individual subsystems (eg mechanical, hydraulic, electrical etc) covering the safety-critical components of the amusement device.

128 If actions need to be taken before the device can be used again, or within a specified time, the inspection body should inform the controller in writing of the necessary requirements.

129 The AIB should ensure that all the relevant inspections required to ensure the continuing safety integrity of the amusement device have been completed and a report issued. A report number, completion date and expiry date should be provided for each report. Once these are confirmed and collated the AIB may then issue a DOC to the device controller.

130 Where an inspection body has completed its inspections, but the final report has not been issued, the AIB may issue a DOC as long as the inspection body concerned has confirmed in writing that the inspections have been completed and the device has been found to be satisfactory. The final report should be sent to the AIB within 28 days of the work being completed.

131 A registered inspection body should not work outside its area of competence, ie the categories of work they have registered with ADIPS Ltd to carry out.

132 An inspection body is not responsible for work carried out by other registered inspection bodies. The individual inspection bodies have a duty to ensure their work is both competent and diligent.

How long is a DOC valid for?

133 The DOC lists the individual inspections that have been done, and the date they were completed. These inspections are normally valid for 12 months from completion, unless a shorter time has been specified. Each of the reports will have an expiry date. The expiry dates of the reports may be different if the individual reports were carried out by different inspection bodies at different times.

134 The DOC expires on the date that the first individual examination reports listed on the DOC expire. The period of time between in-service annual inspections should not exceed 12 months, but may be a shorter period of time if specified in any of the reports or by the AIB.

Role of the appointed inspection body

135 The AIB should:

- confirm that the pre-use inspections (design review, assessment of conformity to design and initial test, or risk assessments if the design is mature (see Appendix 2)), have been carried out and are documented in the operations manual;
- confirm that the relevant in-service inspections are documented in the operations manual;
- make all reasonable enquiries with the controller whether any modifications that may affect the safe operation of the device have been made since the previous DOC was issued and that the design review, assessment of conformity to design and initial test, as required, have been documented in the operations manual;
- confirm that the report of functional test is in the operations manual. The purpose of the functional test is to check that the device operates safely within stated operating conditions.

Preparing for an in-service annual inspection

136 The controller and the relevant inspection bodies should agree the items to be dismantled. It is recommended that this is done in advance to allow parts to be prepared for inspection before the inspection body arrives. Preparation may include degreasing, removal of rust, removal of paint, or other protective finishes. This will normally include the dismantling of complex assemblies to allow access to safety-critical areas.

137 Difficulty of access is not a valid reason for failing to inspect safety-critical components.

138 The schedule specifying the required non-destructive testing (NDT) will also provide information on any disassembly required. See Appendix 5 for further details.

139 Before starting work, the inspection bodies involved in the inspection should:

- check with the controller and in the operations manual to see whether any safety-critical components have been replaced, modified or repaired since the issue of the previous DOC. If so, there may be a need for further inspection or actions as a result of this work;
- check with the controller for any relevant accident or incident history of the device. This will inform them of necessary further inspection or action that may be required;
- check the operations manual to review the service history, identify the safety-critical components and any recommended inspection methods listed.

Recommended procedure for in-service annual inspection

140 The inspection should include, where appropriate:

- visual inspections;
- NDT;
- electrical tests;
- functional tests.

141 An in-service annual inspection should consider all the safety-critical parts of the device. This will normally include the following, where appropriate:

- the condition of mechanical and structural parts of the device. Examples of this are the load-bearing components including the supporting structure, passenger-carrying units, couplings etc;
- any equipment used for assembling or dismantling where it is part of the device;
- the condition and settings of the hydraulic or pneumatic system;
- interlocks, especially those that have a safety function;
- the integrity of the passenger-containment system;
- the integrity of the passenger restraint to make sure that it is in good condition, properly adjustable and functioning correctly. This should include a sample strip down of passenger restraints unless there is a reason for not doing so documented in the operations manual. Any sampling carried out should follow the guidance in paragraphs 144–145;
- the parts of the device which do not normally bear passenger loads, including lighting fittings, guard rails, canopies etc and other decorative features as well as their supporting members (particularly important where such parts could fall or be projected into the path of moving passenger carriages);
- the integrity of the electrical installation, including generators;
- equipment providing motive power;
- control systems, particularly those systems that have a safety function;
- guards and barriers;
- attachments which could affect safe operation, eg theming, lighting supports and access platforms;
- safety equipment which is not designed to function during the normal operation of the device, for example:
  - fall-back arrestors, emergency brakes or other systems providing redundancy and back-up systems;
  - chains and ropes used to retain parts of the device in place in the event of structural failure;
  - integral evacuation equipment.

142 Inspection bodies should make any recommendations for any other inspection or testing that they feel is necessary to allow them to complete their part of the inspection.

143 An inspection body should confirm that devices have been upgraded to avoid danger, where information is reasonably available to them and lies within the remit of the inspection they are carrying out. Sources of information would include safety bulletins from manufacturers, the trade associations, ADIPS, HSE and information received by the controller.

Sampling

144 If a device has a number of identical components which can be individually identified, the appointed inspection body may select a proportion of them and examine that sample in detail. If any defects are found in the sampled components, the remainder will need to be examined.

145 The components sampled should be varied from one inspection to the next, and their identities documented to ensure that over a number of in-service annual inspections all similar components have been inspected.

Functional test

146 An in-service annual inspection should include a functional test. This should not be attempted until any work on safety-critical components, identified as necessary as a result of the inspection, has been completed and the device reassembled. It may require a separate visit.

147 The device should be observed operating (with representative loads if necessary) and the effective operation of safety-related controls checked. The load may be provided by passengers if safe to do so.

148 The observations made should be compared with the operating specifications set out in the operations manual. This includes those for speed controls, stopping devices and any interlocks, for example between passenger restraints and the starting device.

Written report

149 After completing their inspection, each inspection body involved should prepare a written report, including a reference number and dates of completion and expiry. The report needs to list any faults or any areas which require further inspection or testing. It should be clearly stated:

- if the device should not be used – the reason(s) why and a list of defects;
- if the AIB is recommending that the device should only be used under specific limitations (eg under reduced speed or with certain passenger units not used);
- the maximum period of time that the device may be operated before re-inspection of the full device (or named components);
- if after remedial maintenance, repair or testing has been completed, further inspection is required.

150 Once the AIB has collated all the individual inspection reports and by doing so has confirmed that all the relevant inspections have been satisfactorily completed, they may issue a DOC to the controller. A DOC should not be issued until the AIB is satisfied that all necessary remedial actions outlined in the inspection reports have been completed.

151 The controller should keep reports of in-service annual inspection for at least 10 years (indefinitely if possible) to provide a history of the device.

Section E
Guidance for organisers

Role of the organiser

152 Effective organisation of fairs and amusement parks is essential to manage safety properly and control risks. The aim of the organiser is to ensure the safe operation of the fair or amusement park by taking overall responsibility for the management of the risks. The organiser will need to:

- identify any control measures needed to avoid or reduce risks to the public and employees;
- have a policy in place for organising, planning, monitoring, controlling and reviewing activities that affect the safety of people on the site.

153 The organiser may be an individual, a group of people or a company. In practice the identity of the organiser will depend on the following:

- for fixed sites, such as amusement parks, the person or company in control of the overall site will usually be responsible;
- for temporary sites the situation may be more complex:
  - where an individual acts as a licensee, that individual is the organiser;
  - where there is no licensee, then an organiser should be chosen and be given the necessary authority by the controllers present;
  - where the fair is part of a larger event, the promoter will usually be the organiser. The controllers present must co-operate with the organiser.

154 **While individual controllers have overall responsibility for the safe operation of their attractions, the organiser needs to make sure that the actions of these controllers do not affect the overall safety of the site. The organiser should take reasonable steps to ensure that individual controllers have complied with their duties under this guidance. It is imperative that the organiser has the authority to take any necessary action to ensure the safety of the public if it is apparent that a controller is failing to do so.**

Organising

155 As organiser you will need to:

- appoint responsible people to be on duty while the public is on site and make sure they have been trained in the action to take if there is a fire or other emergency;
- make sure that people with specific responsibilities in emergencies are readily identifiable by conspicuous clothing or marking;
- have a named deputy who has the responsibility and authority to act in your place;
- let each controller, operator and attendant know your identity and the names of any deputies, together with all necessary information about the emergency plan, including site address and any relevant telephone numbers;
- identify and mark escape routes and any assembly points and make these known to staff and to the emergency services and others involved with the fair as necessary.

156 Make sure that everyone involved has, at some point, received relevant training in emergency procedures. This does not necessarily mean that you have to do the training, but you should check that it has been done. The training should include:

- how to spot and prevent potential emergencies;
- what to do on discovering an emergency;
- how to raise the alarm;
- how to use emergency equipment;
- how to help others escape to a safe place.

Planning

157 Consult the appropriate authorities and emergency services before the fair takes place (or periodically for fixed sites) to make sure they are aware of what is being planned, and have the opportunity to comment on any proposals being made.

158 Ensure that risk assessments have been carried out that identify what needs to be done with regard to:

- transport and access, eg for both routine transport movement and emergency vehicles;
- emergency situations, including evacuation, which could arise from:
  - fire or explosion;
  - major failure of an attraction;
  - severe weather conditions;
  - overcrowding or crowd disturbances;
  - any other reasonably foreseeable emergencies, which will depend on the nature, size and location of the site.

Emergency plan

159 Make sure you have appropriate emergency procedures in place for the duration of the fair. You should have prepared a written emergency plan before the fair starts, or, in the case of a fixed site, before it opens to members of the public. The detail and complexity of any plan will depend on factors such as the size of the fair or fixed site, its location, duration and the likely number of visitors. The risk assessments for the fair should provide a focus for areas that need to be considered.

160 The emergency plan should be made available to controllers, the emergency services and the local authority. It should include:

- a list of people with allocated responsibilities and their contact details;
- stewarding arrangements (stewards should not be involved in the operation of amusement devices);
- conditions agreed with the emergency services, such as:
  - liaison arrangements;
  - rendezvous points, entrances, and emergency routes;
  - the location of services (eg water, electricity etc);
- evacuation procedures;
- contact details for the relevant emergency services;
- a layout plan of the site. This should include, where appropriate:
  - device locations;
  - entrances, including access for emergency services;
  - pedestrian and traffic routes;
  - position of control centres;
  - location of services (eg water hydrants, electrical substations etc);
  - assembly positions.

161 Plan the layout of attractions so that:

- risks arising from the site such as uneven or soft ground, wind uplifts or from another structure or overhead power-lines, are minimised;
- there are no points where channelling the public could lead to dangerous overcrowding in an emergency. Extra space may be needed around popular attractions;
- there is sufficient space to allow access for emergency vehicles (including access to fire hydrants), at the same time as the public is evacuated. Don’t forget that access routes will need to be able to cope with people with disabilities or families with children and pushchairs;
- there are identified access routes that can take the weight of all vehicles. Remember that emergency vehicles and recovery equipment, eg cranes, may need to access the site;
- the ground or structures used are suitable to take the weight of all anticipated people, plant and vehicles;
- there are safe distances between attractions and perimeter walls, fences etc (this includes any barriers and waiting areas), taking into account:
  - the motion and passenger clearance envelopes of amusement devices;
  - the need for emergency access and egress (pedestrians and vehicles);
  - segregation of the public from dangerous moving parts or areas of danger.

162 For coin-operated passenger-carrying amusement devices, distances between them may vary, as long as any necessary safety envelope is not compromised.

163 Ask advice from the local electricity company to find out if power lines cross over or under sites where attractions will be placed. Make sure controllers are aware of the risks and relevant precautions. Further advice is available in Guidance Note GS6 *Avoidance of danger from overhead electric powerlines*.[6]

164 If the fair is likely to disturb the ground or if significant loads are to be placed upon it, you as the organiser should obtain relevant information on underground services from the owner of the land and the local utility suppliers. Pass this on to the controllers and plan the fair to minimise the need for them to place poles or pegs near such services, or to place load-bearing structures where the ground is not suitable, eg above voids. Use cable-locating techniques before any excavating is done. Further information is given in HSG47 *Avoiding danger from underground services*.[7]

165 Some sites, for example those used for street fairs, may have restricted or difficult access. In such cases you may need to plan the times of arrival and departure of the attractions to minimise the risks to members of the public passing through the area during build-up and pull-down. If necessary, seek permission to restrict access by the public during these times.

166 Check before the fair starts that all controllers have current insurance and that for each device there is a current Declaration of Operational Compliance (DOC) from a registered inspection body with a relevant set of reports in its operations manual to show that it is fit for use.

167 Employers have duties under the Health and Safety (First Aid) Regulations 1981 to make first-aid arrangements for their own employees.[8, 9] **It is strongly recommended that you make arrangements to provide first aid for members of the public**. Providing trained first-aiders for the public should be seen as an important part of your emergency planning.

168 If you are planning a firework display on your site you are strongly recommended to use a professional company and consider the guidance in HSG123 *Working together on firework displays*.[10]

Managing the site

169 To manage the site effectively you need to:

- be available on site, or be represented by a deputy, whenever the site is open to the public;
- establish a means of communicating with controllers, the public and the emergency services;
- identify and mark any area prohibited to the public;
- make sure that fire and other safety checks are carried out each day before the public is admitted, for example, that:
  - a system for raising the alarm is in place;
  - fire escape routes are unobstructed and all fire exit signs are clearly visible;
  - there are no obvious hazards (eg deteriorating ground conditions);
  - fire instruction notices are displayed;
  - fire-fighting equipment is available.

Monitoring the site

170 Make sure that safe conditions are maintained in and around the attractions throughout the day by:

- monitoring individual attractions;
- checking for overcrowding and re-routing the public if necessary;
- keeping all routes, including emergency routes, clear and well signposted;
- monitoring the condition of the site, particularly housekeeping and the state of the ground, and that waste paper and other flammable materials are not allowed to accumulate where they may be a source of danger;
- checking that the layout stays as planned.

Review your procedures

171 For a temporary site, review the effectiveness of your procedures at the end of the fair. For a fixed site, review procedures at regular intervals. Use the findings in future planning. Include a review of effectiveness of the organisation with your own staff, family members and colleagues.

Section F Guidance for controllers

Safe operation

172 The safety objective for controllers is to ensure that the initial integrity of a device is maintained, and that it is operated safely in respect of the risks to employees and the public. This can be achieved through the lifetime of a device from pre-purchase enquiries to eventual sale by:

- following the Amusement Devices Inspection Procedures Scheme (ADIPS) for pre-use and in-service inspections (see Section D);
- ensuring the required documentation accompanies buying and selling (see paragraphs 174–180 and Section C);
- safely modifying and repairing (see paragraphs 181–186 and Section C);
- effective maintenance (see paragraphs 190–199);
- safe systems of operation (see paragraphs 201–245);
- training operators and attendants (see paragraphs 246–256);
- maintaining the operations manual (see paragraphs 176, 179, 185–186, 192 and Appendix 3);
- following emergency procedures (see paragraphs 257–264);
- periodically reviewing the effectiveness of the above.

Responsibilities of controllers

173 You are responsible for the safe operation of all your devices. You may delegate tasks, but overall responsibility remains with you at all times. You must also:

- co-operate with others, for example the organiser, other controllers etc to ensure safety;
- report any failures or injuries when required. By reporting an incident you are not admitting liability, but if you do not report it, that is a criminal offence (see paragraphs 261–263);
- assess the risks on site to identify the control measures required to ensure your devices operate safely.

Buying or selling a device

174 Devices come within the definition of ‘work equipment’ in the Provision and Use of Work Equipment Regulations 1998 (PUWER), with the exception of coin-operated devices designed for unattended use. Duties under PUWER apply to all employers and to self-employed people – see HSE leaflet *Using work equipment safely* for further guidance.[11]

175 If you directly import fairground equipment you assume the legal duties of the designer, manufacturer and supplier. You may be in breach of the relevant legislation for any failures or injury that result from the design or manufacture of a device unless you have taken reasonable steps to check that it complies with legal requirements and this guidance. You can do this by following this guidance and using an inspection body registered with ADIPS to carry out pre-use inspections (design review, assessment of conformity to design and initial test) to confirm that you have satisfactorily addressed these duties (see Section D).

176 You should not use an amusement device unless you have suitable documentation in English, either the relevant pre-use inspection reports or a

suitable maturity risk assessment (this will depend on the age of the ride and the date it was manufactured or imported – see Section D). A device should have an operations manual consistent with Appendix 3 of this guidance. This should also be in English. Without this documentation you cannot be certain that everything necessary to make the device safe has been done. In the case of coin-operated amusement devices an initial test report and instruction manual is sufficient.

177 If you acquire a second-hand device, the current Declaration of Operational Compliance (DOC) should be re-issued by an inspection body in the name of the new controller. If the device was designed to be permanently installed and has been moved to a new site, this should be considered a safety-critical modification and subject to the relevant pre-use inspections.

178 If you sell, hire or lend out any device second-hand you become a supplier. You must comply with section 6 of the HSW Act for fairground equipment (see Appendix 1).

179 If you sell a device second-hand you should provide the buyer with the operations manual (see paragraphs 66–69 and Appendix 3). There will be some older devices for which the operations manual is incomplete. In these cases as much of the device history as possible should have been gathered to form the manual. For coin-operated amusement devices it is sufficient to have an instruction manual.

180 If you hire or lend out a device you should ensure that it is in a safe condition, has adequate operating instructions, a current DOC and have suitable systems in place for inspecting and maintaining it when it is returned and before it is rehired or re-lent out. In the case of inflatable devices a PIPA certificate will also be acceptable.

Modification and repair

181 Before modifying any device, make sure that the proposed modification will be safe.

182 A safety-critical modification includes any change to:

- loading (eg changing seating arrangements, fitting heavier passenger units);
- speed or operating cycle;
- range (eg height of lift);
- safety envelope;
- safety-critical components, devices or systems;
- structural and mechanical components;
- drive mechanisms;
- control mechanisms (eg brakes, shock absorbers, speed limiters, speed or position sensors);
- software;
- passenger containment (including fencing and barriers);
- passenger height restrictions.

183 It will also include:

- use of a device outside its specification or normal environment for which it was designed;
- reinstallation of a fixed device in a different location.

184 If in doubt, it should be assumed that every modification is safety-critical and the advice of a competent person should be sought.

185 Before using any device following a safety-critical modification, you need to obtain and enter in the operations manual the following documents relating to the modifications:

- report of design review (see paragraphs 101–103);
- report of assessment of conformity to design (see paragraph 109);
- report of initial test (see paragraph 122).

186 After a repair do not use a device until:

- every repaired part has been checked against the specification and/or procedure. If there are differences you should treat the repair as a modification;
- details of the repair and any relevant tests and inspections are recorded in the operations manual. For coin-operated amusement devices, the details may be recorded in any suitable way.

Inspection and test

187 Ensure that all necessary pre-use inspections (or design maturity risk assessment for older rides – see Appendix 2) have been carried out on a device before it is brought into service for the first time. Also ensure that each device is subject to in-service annual inspection and that it has a current DOC. Only use an inspection body that is registered with ADIPS to carry out pre-use and in-service inspections. See Section D for information on inspection bodies and types of inspections.

188 In some cases the manufacturer, supplier or the inspection body may recommend more frequent inspections. Other types of examination may also be necessary (eg statutory examinations such as for pressure systems, lifting equipment etc) or if safety-critical parts of the device have been modified or repaired.

189 Never operate a device beyond the expiry date on the DOC.

Maintenance

190 The process of pre-use and in-service inspection is important as part of the system to ensure a device is safe. However, these inspections are not enough to ensure that a device is adequately maintained in a safe condition. You are responsible for making sure that additional periodic checks and inspections are done to make sure a device remains in a safe condition during the period it is being operated.

Daily check

191 **Note:** Paragraphs 192–194 may not be relevant to coin-operated amusement devices, but those responsible for such equipment are strongly recommended to check daily for damage and to make sure that the device is working properly.

192 Make sure that each device has a daily check before the public uses it. For an amusement device the daily check needs to be in writing, filed in the operations manual and:

- take account of any instructions from designers, manufacturers, importers, suppliers and inspection bodies;
- list all parts and other matters which need daily checking to ensure safety and describe how they should be checked;

- include, where appropriate, details of the extent of acceptable variations, eg out-of-level, air pressures, torque settings, wear;
- check that safety controls, brakes and other safety devices, including communication systems, operate effectively (these should be done daily unless it can be shown that a longer periodic inspection is appropriate);
- include checks to make sure that barriers, guards, walkways etc are in place and in good condition, and that all locking devices and securing pins are in place and in good condition;
- ensure that cabinets, boxes, enclosures etc containing hazardous equipment and/or substances are suitably secured;
- for a ride, require at least one complete operating cycle.

193 Make sure the person doing the daily check is sufficiently trained and experienced to do it properly. It is good practice to keep records of any relevant training provided. Keep records of daily checks and of any remedial action taken, if possible for at least three years in such a way that the records can be examined if needed.

194 Do not open a device to the public unless the safety measures the daily check has shown to be necessary have been taken.

Periodic maintenance

195 You must properly maintain and service work equipment, which includes amusement devices. Make sure that maintenance work is done:

- by people trained or experienced in the procedures appropriate for that equipment;
- taking account of the manufacturer's instructions and maintenance schedules. Where they are not specified seek the advice of a competent person.

196 It is good practice to have a supply of common components (eg springs, catches etc) and to have a programme of planned preventive maintenance aimed at replacing components before they reach the end of their useful lives. An important part of maintenance is condition monitoring, ie the recording of the condition of components and performance of systems at regular intervals so that gradual changes can be detected, for example, on a ride:

- Is the travel on a control lever increasing?
- Is the ride taking longer to stop?
- Are the readings on pressure gauges changing?

197 Welding or other hot work may be needed as part of maintenance. It is possible that by doing welding, you may be making a safety-critical modification. If so, it will require a design review, an assessment of conformity to design and/or an initial test.

198 Do not repair cracks in any device without consulting the manufacturer or a registered inspection body. The manufacturer needs to know if there is a problem, so that causes can be investigated and remedied. The manufacturer may then want to make recommendations about the repairs and/or safe operating conditions. If any welding is done, make sure that the correct materials and techniques have been used so that the integrity of the device is not affected.

199 Before operating a device following maintenance, make sure that any protective devices, eg guards, fences, doors, interlocks etc, which may have been removed, are replaced, secured and are operational.

Safe systems of operation

200 Paragraphs 201–245 give practical guidance on how safe systems of working can be adopted by controllers.

Siting of amusement devices

201 You must co-operate with the organiser to assess any site risks (see Section E).

202 Make sure that each device is erected on ground or a structure which:

- can safely bear the load;
- is stable and suitable for the device to be built up and used safely.

203 Take account of any manufacturer's instructions relating to operating conditions such as wind speed and make sure that adequate anchoring points have been used.

Transporting, assembling and dismantling devices

204 When transporting, assembling or dismantling:

- move devices in a way that minimises the risk of damage to safety-critical components. Make sure that all loads are properly secured during transit;
- be very careful when moving vehicles on site. Carry out vehicle movements in accordance with any instructions from the organiser;
- avoid moving vehicles if there are members of the public or young children in the area;
- avoid reversing where possible, and where it is unavoidable take reasonable precautions;
- assemble and dismantle each device in accordance with the manufacturer's instructions using trained personnel or people under supervision.

205 During assembly and dismantling, use any temporary guys, stays, supports and fixings needed to prevent danger from the collapse of any part of the device. Provide enough lighting for it to be done safely and take all reasonable steps to exclude the public and others who are not involved in carrying out the work.

206 Lifting equipment falls under the requirement of the Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)[12] and should be thoroughly examined, tested and inspected (see Appendix 1) either:

- in accordance with legal requirements; or
- if it is a part of the device required to allow it to operate as an amusement device, to the same standard as required for the remainder of the device.

Assembling component parts

207 Have procedures to make sure that safety-related components are:

- individually identifiable if they look the same but are not interchangeable;
- stored to minimise the risk of deterioration and contamination;
- examined for signs of wear, deformation and damage when being assembled;
- cleaned and lubricated as necessary before being incorporated into the structure;
- carefully assembled so they are not damaged, for example, they should be correctly aligned and not bent, distorted or unduly forced;
- assembled using appropriate fastening and securing components which are properly used and correctly adjusted. In particular:
  - 'R' clips should be the right size, in good condition and correctly fitted;
  - split pins should be spread effectively;

  - self-locking nuts should not be used more times than recommended by the manufacturer;
  - recommended torque settings should be applied;
- not thrown, or dropped where this is likely to injure people or damage equipment.

208 If you find components that are damaged or have excessive wear, replace them with parts consistent with the design specification before you use the device again.

209 If you find repeated or unusual damage to safety-critical components, seek specialist advice as it could indicate a fault developing on the device.

210 If your risk assessment identifies a significant risk arising from the failure of a single component you may need to check these components more carefully and frequently than others. Where the risk is found to be high you may wish to make a modification which will require design review.

Operational stability and safety

211 Travelling amusement devices can be assembled and dismantled several times over the course of a season and even fixed devices may be moved on occasion. The assembly process should take into account the need to make sure they are stable and secure before they are put into service.

- Check that all the structural members needed for stability and safety are correctly used and that appropriate packing is provided.
- Level and pack each device according to the manufacturer's instructions, where available, making sure that loads are adequately distributed and firmly supported. Where practicable, place the packing directly beneath the load points. If you cannot do this, use a supporting structure suitable for transmitting the loads safely through the packing to the ground.
- Use only suitable packing materials and place them to prevent slipping or sinking. Keep the number of packing pieces to the minimum consistent with safe operation. Never rely on hydraulic jacks to support a device. Check packing regularly.
- Check the ground regularly after a device has been built up to confirm that its load-bearing capacity has not deteriorated.
- For a device with rail tracks, lay them so that the passenger-carrying units run safely and smoothly over them. Where required, clearly mark pedestrian crossing places and make sure the surfaces are level enough to prevent trips and falls.

Preventing access to dangerous moving parts and areas

212 A major risk is that of people coming into contact with dangerous moving parts of rides. Your risk assessment (see Section B) should identify appropriate control measures such as:

- barriers;
- interlocks or locking-off points and procedures;
- platforms;
- steps;
- marking danger zones;
- notices;
- staff training;
- supervision.

213 In many cases you will need to use more than one control measure. Where your control measures include supervision, operators and attendants will need appropriate training. You have responsibility to ensure the safety of your staff as well as the public. Many employees are 'run down' by rides, particularly when collecting fares or doing maintenance.

Barriers
214 Providing a suitable barrier is often the most effective way of preventing access to danger areas or dangerous parts. If the barrier protects an edge from which somebody could be injured if they fell, the barrier should have a top rail (at least 1100 mm high), a toe board and a mid-rail to ensure that the maximum gap between it and the top rail/toe board is 470 mm. These barriers should be designed to prevent people from becoming trapped in or falling through them.

215 Keep access points between barriers to the minimum size and number needed for safe loading and unloading as identified by your risk assessment. Do not have more than four access points nor make them so wide as to defeat the point of having barriers or make effective supervision of the gap impracticable. Some rides supplied with 'open fronts' may need additional barriers.

216 While the ride is in motion, prevent people from passing through gaps in barriers unintentionally by:

- placing an attendant at a safe position at each access point or effectively barring the access gaps;
- providing the access points with offset barriers/and or steps.

217 All barriers need to keep people outside the safety envelope of the device. If parts swing out over public areas, these areas may need to be enclosed where any part of the device or a passenger will be less than 2.5 m above the ground.

218 In some circumstances, it may not be possible or necessary to use a barrier. In these cases the platform of the ride may provide a sufficient barrier where it can be justified by risk assessment, based on factors such as the height of the platform, the projection of moving parts of the ride outside the limit of the platform, entrapment risks and the speed of the ride.

219 Coin-operated amusement devices may not require barriers unless the motion presents a significant risk.

Access to danger areas
220 On some devices with raised platforms, there may be a danger area underneath the platform. Take care to prevent access to such areas, particularly if building up a device on sloping ground.
221 Highlight danger areas by notices, painted lines etc. Provide sufficient supervision to make sure that people do not stray into danger areas. Although supervision is important, it should not be a substitute for physical measures.

222 Where appropriate, provide a safe area for waiting members of the public and make any arrangements necessary to control them. These may include providing additional supervision and/or features such as queuing rails and gates.

223 On dark rides, provide emergency exit routes which are well-lit and signed when required. Control risks to prevent tripping or falling, particularly where the routes cross or run alongside rail tracks.

224 Before using any device, securely fasten any covers or barriers over openings to prevent access to dangerous parts of machinery. For further information see BS EN 294:1992 *Safety of machinery. Safety distances to prevent danger zones being reached by the upper limbs*.[13]

Electrical safety

225 Amusement devices should be maintained in an electrically safe condition. The annual in-service inspection is not a substitute for effective maintenance and periodic checks for safety. Any work carried out on electrical parts of amusement devices should be carried out by suitably competent persons.

Falls from height

226 Amusement devices require assembly and dismantling, inspection and maintenance which may all involve people working at height. Where possible you should plan the work to eliminate the need to work at height, eg by assembling as much of the device as possible at ground level. Where work at height is necessary it should be carefully planned and suitable safe systems of work introduced.

227 Employees should be properly trained in the work to be done, and in the use of adequate personal protective equipment (eg fall-prevention, fall-arrest and work-positioning equipment). It is very important where work at height is expected that you have an emergency rescue procedure in place to recover someone who may have fallen and is suspended (eg from a lanyard or inertia reel and harness system). There is a serious risk from suspension trauma if the person is not rescued within a short space of time (which can be as little as 10–15 minutes). See Appendix 4 for details of how to carry out a work at height risk assessment.

Safe systems for operating devices

228 The information in Section G on safe operation of devices by operators and attendants is also relevant to controllers but is not repeated here.

229 Keep records of what you and others have done to ensure safety. You may be asked for documents by organisers, lessors, HSE or trade associations seeking evidence that your device is being operated safely. Depending on the type of device, these may include:

- significant findings of risk assessments;
- maintenance, modification and inspection records;
- instructions for operators and attendants;
- training records.

230 Have a system for securing devices and immobilising rides not open to the public and take reasonable steps to prevent public access at these times.

231 Ensure when each device is open to the public (except those designed for unattended use) that:

- it is in the immediate charge of an operator;
- the operator is in control of the device throughout the cycle;
- no operator is in charge of more than one operating device at any time;
- no device is used outside the operating conditions specified in the operations manual or any other condition specified by an inspection body;
- no unauthorised person interferes with it except to use an emergency stop, if appropriate, readily identifiable to the public.

232 Safe operation also includes making sure that non-users are not put at risk. Some of the things you may need to do to protect them include:

- not allowing the public to wait in places of danger;
- providing enough attendants to control access points and, where appropriate, queuing areas. The number of attendants will depend on the size of the crowd;
- making sure that waiting or loading areas are not overcrowded or overloaded;
- not allowing a ride to be started until it has been confirmed that it is safe to do so;
- providing notices or using a public address system to give information to the public and help attendants enforce your rules;
- making sure that all staff are readily identifiable.

233 Where operators do not have a clear view of all loading or unloading points, devise a clear system of signals for checking with attendants that it is safe to start. Make sure every person using the system is instructed how to use it and display a copy of the signal code in appropriate positions.

234 When there is a foreseeable risk of collision between cars on a tracked ride, a suitable system should be in place to control the risk of injury, eg a series of brakes designed to prevent collision.

235 Assess how weather conditions can affect the safety of your device, for example:

- What conditions will require additional inspection of packing and anchors?
- At what wind speed should you close the device, removing lighting or backdrops or provide additional anchorage?
- What parts become slippery or less effective when wet?

Passenger containment

236 The main risks to passengers on a ride are:

- contact with parts of the ride outside the passenger unit;
- ejection due to the motion of the ride;
- falls from the ride;
- injury arising from the forces imposed by the motion of the ride, including during emergency stops;
- foreseeable passenger misuse.

237 You should have a knowledge of how the designer intended the passenger containment to be used, particularly the use of passenger restraints. Always follow instructions given by the designer on passenger containment, eg physical restrictions. Any alteration to any part of the passenger-containment system will require a design review to be carried out by an inspection body registered with ADIPS.

238 Do not add parts to the device (eg theming) that could adversely affect the clearance between each passenger-carrying unit and other parts of the ride. Any alterations that may affect safety clearance distances will require a pre-use inspection procedure by an inspection body registered with ADIPS.

239 Check that all components of the passenger-containment system including seats, bars, belts, harnesses, handholds, footrests, locks, catches, hinges and other attachment points are properly maintained and correctly adjusted so they will be secure and minimise injury from the motion of the ride. Do not use any part of a ride where the passenger-containment system is defective.

240 Take reasonably practicable measures to identify and exclude any individuals who cannot ride safely if, for example:

- they are too small to be safely contained;
- they are too large to be safely contained;
- they have a disability or other condition, eg back or neck injury, heart condition, or they are pregnant;
- they are behaving inappropriately.

241 Like all service providers, you must consider what you need to do to comply with the Disability Discrimination Act 1995.[14] This law gives disabled people rights to access your rides and you may have to make 'reasonable adjustments' to help. For more details see Appendix 1, paragraphs 55–58.

242 Size limits of passengers should be specified in the operations manual and followed by controllers. If passengers within the size limits cannot reach the main components of the containment system or otherwise ride safely they may not be suitable to ride on the device. Where this situation arises frequently, you should seek further advice on passenger containment from a person competent in the design of passenger-containment systems. Treat any proposed change of size limits as a safety-critical modification.

243 Help operators and attendants enforce any passenger exclusions by having prominent notices or pictograms which clearly set out any restrictions specified by the designer, or design review body. Where appropriate use the public address system to reinforce the need for passengers to follow safe riding procedures.

244 Make sure:

- the operator and attendants give clear and appropriate instructions to passengers on their conduct and that they check all adjustable restraints before each ride;
- if passengers can be stranded away from their normal unloading point they can be moved to a place of safety without risk or undue delay, preferably in the unit in which they are travelling. There should be procedures suitable for everyone using the device that are understood by the operator and attendants. On dark rides staff should be able to tell passengers how to get to emergency exits.

245 Train, instruct and require operators and attendants to take reasonable steps, including stopping the device if necessary, to prevent passengers:

- intentionally misusing equipment provided for their safety;
- behaving recklessly;
- recklessly disregarding clear and reasonable instructions.

Selecting and training staff

246 Controllers should be competent to carry out safety-related tasks, or ensure the competence of others who carry out such work for them. Key safety-related tasks in relation to amusement devices are daily checks, inspection, repair, maintenance, supervision and operation.

247 Make sure employees are competent in the work they are expected to do. This involves employee selection, training, monitoring and keeping records. The levels of competence required will depend on the nature of the work, and this should be identified by a risk assessment.

248 Select people who have a work attitude that puts the safety of the public first and who are likely to be conscientious and reliable in following this guidance. Look for people who have the maturity to:

- be reliable and have the necessary authority;
- give confidence to the public, particularly on children's and family devices.

249 Do not allow anybody under the age of 18 to operate the following:

- a ride (except simple slow-moving rides designed for use by children);
- a shooting gallery where hazardous projectiles are used;
- an enclosed structure which holds more than 30 people or is intended primarily for the amusement of children.

250 Operators of other devices should be least 16 years old. Every attendant who performs a safety-related function should be at least 16 years old. All work relating to the containment of passengers should be considered safety-related.

Information and training

251 You must provide adequate information and training to all employees. Training should be appropriate to the risks and given in a way that people can understand. You may need to liaise with other people to help, for example, with fire precautions training.

252 General information and training for all employees involved in running a device need to cover at least the following areas:

- general health and safety requirements relating to the device;
- safety of the device(s) to be used;
- the importance of daily checks, maintenance and inspection programmes and the need for competence in the work to be done;
- site safety;
- dealing with problems to include:
  - procedures for managing people who misbehave/are distressed etc;
  - how to deal with defects and malfunctions;
  - reporting procedures for accidents/incidents;
  - emergency procedures;
  - adverse weather conditions.

253 You are strongly recommended to keep a record of any training given and any tests of how well the employees understand it.

254 Operators and attendants of devices will need specific information and training on:

- systems of work for operating a device safely;
- safe loading/unloading of the device;
- details of any passenger restrictions, for example height, weight or medical conditions;
- safe waiting/viewing places for intending passengers and spectators;
- using the passenger-containment system, including checking closure of passenger restraints where necessary.

255 Staff will need regular training and refresher training especially after changes caused by a safety-related modification (see paragraphs 182–186) or changes to your procedures or a change in the way you manage the public. If you change lighting, introduce smoke or alter the access points to a device you will need to assess these effects and whether procedures should be changed.

256 You should also have a system for monitoring staff to check that they are following your instructions.

Emergency procedures

257 Risks at fairgrounds and amusement parks can arise from:

- fire;
- major failure of a device;
- severe weather;
- other factors, eg criminal behaviour.

258 You should have procedures for foreseeable emergencies that may affect the site. These should be identifiable by a risk assessment (see Section B).

259 If the emergency involves your device, you may have different groups of people to consider, for example:

- passengers who may be young, old or have disabilities;
- other spectators (some of whom might be relations of passengers and therefore distressed);
- employees;
- public and employees on nearby attractions.

260 Make sure your staff know what to do if there is an emergency. This should include taking reasonable steps to test your emergency procedures to ensure they are effective.

Accidents and incidents

261 Instruct your staff to report to you as soon as possible any accident or incident which causes injury or damage, including threats or acts of violence. Deal with any casualties first, but after the incident report the event.

262 Certain injuries and incidents are reportable to the enforcing authority by the 'responsible person'. This person is likely to be:

- the controller if the incident occurs at a device; or
- the organiser if it occurred elsewhere on the fairground.

263 Further information is given in *A guide to the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995* (RIDDOR).[15]

264 If it is possible that a defect on a device could lead to danger, do not allow the public to use it until you are satisfied that the cause has been identified and remedied. This may include checking all similar components in addition to the one giving rise to the fault. If you have any doubt about the continued safety of a device, do not allow it to be used until a competent person (eg an inspection body) has confirmed that it is safe to do so. Keep records of all incidents and the action taken in the operations manual as you may need to:

- give details to HSE, your trade association, insurers, the designer, manufacturer or supplier;
- discuss the safety implications with an inspection body;
- provide a detailed operational history of the device, for example for a buyer.

Review

265 Review your safety arrangements regularly, for example at the beginning of each season, and make any changes necessary to maintain or improve their effectiveness.

Section G
Guidance for operators and attendants

Safe attraction

266 Operators and attendants need to do everything reasonably practicable to make sure employees and others are safe in areas under their control. You should make every effort to understand the nature of the device you are responsible for, including where necessary reading and discussing the relevant operating instructions, inspection reports and any other information provided by the ride controller. You can make sure an attraction is safe by:

- understanding your general responsibilities (paragraphs 267–268);
- carrying out daily checks (paragraph 269);
- safe operation (paragraphs 270–275);
- proper supervision (paragraphs 276–284).

General responsibilities

267 You as operators and attendants must:

- follow your employer's instructions relating to safety;
- report incidents and safety hazards immediately;
- not misuse anything provided for health and safety.

268 The dangers of deliberate misuse are obvious, but you should also make sure that you do not alter things unintentionally, for example, making an unauthorised adjustment to the catch of a lap bar to make it easier to use might be misuse if it reduces its safety.

Daily check

269 Before a device is opened to the public, you need to carry out a daily check, including a trial run. Check that everything is working properly and report anything unexpected, or that you think might be wrong (see paragraphs 191–194).

Safe operation by operators

270 Make sure when the device is open to the public that:

- your employer has provided adequate training and information to you to allow you to operate it safely. Inform your employer if you are unsure of your ability to operate the ride safely;
- you are in immediate control at all times;
- the minimum number of attendants needed for safe operation are on duty;
- no one other than yourself, an attendant, or a trainee under direct supervision interferes with the operation of the device, except to use an emergency stop in an emergency situation;
- your full attention is given to safe operation – do not operate more than one device at a time;
- attendants wear distinguishing clothing such as caps, uniforms or arm bands etc.

271 Do not operate the device outside the operating conditions in the operations manual, or any other condition that has been set by the controller or an inspection body.

272 Make sure that you load the device to accommodate all users safely. This may include:

- making sure that people for whom the device may be unsuitable are excluded;
- taking all reasonable steps to exclude those whose behaviour suggests they may not be able to use the device safely;
- on a ride:
  - loading cars in a particular pattern, for example the largest/smallest passengers in the correct position;
  - correctly balancing the cars and the ride;
  - not allowing passengers to use any part of the ride where the passenger-containment system is defective;
  - making sure that all passengers are safely contained and no spectators are in a dangerous place before starting.

273 Remain aware at all times of the factors which may affect the safety of the device, in particular:

- bad weather conditions, for example:
  - strong and gusting winds;
  - heavy rain which may make the ground soft;
  - lightning;
- changes in the way the device is running;
- deviating from operating procedures;
- unsafe behaviour by attendants including horseplay and the effects of taking drink or drugs;
- dangerous overloading or congestion of loading platforms or access points;
- unsafe behaviour by users or spectators.

274 Make sure you follow the controller's instructions to deal with any problem. This might include stopping the device or making it safe.

275 Where you do not have a clear view of all loading or unloading points, or all passengers, use positive signals to check with attendants that it is safe to start. Make sure that every person using the signalling system clearly understands each signal. Do not allow smoke, lighting or other effects to block your view.

Supervision by operators

276 It is important that you as operators watch closely the behaviour of attendants and members of the public. Take immediate action if attendants behave in an unsafe way, fail to follow procedures, are distracted or set a bad example. If attendant misbehaviour is serious or repeated, tell the controller. Set a good example yourself.

277 Make sure that you and the attendants know about what people should, and should not do, and these rules are followed, for example:

- not to carry loose personal possessions, eg handbags, umbrellas or wear clothing such as scarves where these might create a risk by being dropped, ejected or becoming trapped in moving parts;
- where to place hands, feet etc particularly where passengers need to brace themselves against the forces they will experience;
- not to ride if they have certain injuries or are pregnant or for any reason cannot be securely contained.

278 Do not operate any device unless all passengers:

- have been safely loaded;
- are safely contained in the correct position with any passenger restraint or other device physically checked to make sure it is correctly fitted and adjusted properly. Physical checks are essential because of limitations in automatic systems;
- have been told anything they need to know for them to ride safely. Where necessary, remind them over the public address system before starting the device.

279 When operating a device, keep watching to make sure that passengers remain safely contained and that no spectators are moving into places of danger. Where appropriate use the public address system to give any necessary warnings. If you see any person who appears to be going to fall out, climb out, be hit by part of the ride, or otherwise could be at risk, stop the ride or make it safe as soon as you can.

280 Any ride (or part of a ride, eg an individual car) taken out of service for any reason needs to be conspicuously marked and the controls locked in an inoperative position where applicable.

Attendants

281 Follow the instructions given to you by the controller and/or operator. Give your full attention to the safe operation of the device. Constantly watch out for the safety of the public and the people you work with. In particular, make sure you follow the operator's or controller's instructions about loading passenger cars and controlling spectators, for example:

- load cars in any necessary particular pattern with largest/smallest passengers in the right position, where applicable;
- correctly balance the device, where applicable;
- exclude passengers who may be physically unsuitable and take all reasonable measures to exclude those whose behaviour suggests they may not be able to ride safely;
- do not allow passengers to use any part of a ride where the passenger-containment system is defective and may put passengers at risk;
- make sure all passengers are safely and correctly contained and that no spectators are in places of danger;
- indicate to the operator by a positive signal that the ride is ready to start.

282 Make sure you remain able to communicate effectively with the operator. Make sure that passengers stay safely inside the ride and that no spectators are moving into places of danger, for example walking onto the ride. Where appropriate, give verbal warnings. If you see any person who appears to be at risk of falling, ejection or contact with part of the ride, tell or signal the operator immediately.

283 Make sure people leave safely when the ride finishes.

284 Do not:

- ride in an unsafe way or position;
- jump on or off a ride if it could be dangerous;
- encourage or allow passengers to adopt unsafe positions or practices;
- be distracted while the ride is operating;
- tell or signal the operator to start a ride until:
  - you have physically confirmed that all passengers are safely contained with any passenger restraint or other device correctly fitted and properly adjusted;
  - passengers have been given any information needed for them to ride safely;
  - operators, attendants and spectators are in a safe place.

Appendix 1
Relevant legislation

Introduction

1 Sections A to G in this book provide the practical information to enable dutyholders to comply with health and safety legislation. There are a number of different pieces of legislation, and at first glance these can appear daunting. However, the basic requirement is the same:

- identify and assess the risks;
- take action to manage those risks;
- monitor to ensure action takes place; and
- check that it is effective.

2 It is also worth remembering that where a piece of legislation requires a risk assessment that has already been carried out under other legislation, it need not be repeated.

3 The main legislation covering the various hazards and work activities found within fairgrounds and amusement parks is listed, followed by a brief outline of the duties imposed.

Health and Safety at Work etc Act 1974

Management of Health and Safety at Work Regulations 1999 (SI 1999/3242)

Provision and Use of Work Equipment Regulations 1998 (SI 1998/2306)

Manual Handling Operations Regulations 1992 (as amended) (SI 1992/2793)

Lifting Operations and Lifting Equipment Regulations 1998 (SI 1998/2307)

Workplace (Health, Safety and Welfare) Regulations 1992 (SI 1992/3004)

Work at Height Regulations 2005 (SI 2005/735)

Personal Protective Equipment at Work Regulations 1992 (SI 1992/296)

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (SI 1995/3163)

Health and Safety (First Aid) Regulations 1981 (as amended) (SI 1981/917)

Health and Safety (Consultation with Employees) Regulations 1996 (SI 1996/1513)

Safety Representatives and Safety Committees Regulations 1977 (SI 1977/500)

Health and Safety (Safety Signs and Signals) Regulations 1996 (SI 1996/341)

Regulatory Reform (Fire Safety) Order 2005 (SI 2005/1541)

Control of Noise at Work Regulations 2005 (SI 2005/1643)

Control of Substances Hazardous to Health Regulations 2002 (as amended) (SI 2002/2677)

Electricity at Work Regulations 1989 (SI 1989/635)

Disability Discrimination Act 1995

Health and Safety (Enforcing Authority) Regulations 1998 (SI 1998/494)

Construction (Design and Management) Regulations 2007 (SI 2007/320)

Health and Safety at Work etc Act 1974 (the HSW Act)

3 This is the primary Act governing health and safety in the fairground and amusement park industry. It applies to all employers and self-employed people. The Act protects not only people at work but also members of the public and volunteers who may be affected by a work activity.

Duties of employers to employees

4 All employers have a duty under section 2 of the HSW Act to ensure that the health, safety and welfare of their employees are protected when they are at work, so far as is reasonably practicable. In practical terms, fairground and theme park controllers must ensure they provide a place of work that is safe and without risk. They should ensure that:

- safe working practices are set and followed;
- machinery and equipment is properly maintained and safe to use;
- equipment and harmful substances are used properly and stored safely; and
- employees have healthy working conditions.

Duties of the self-employed

5 Self-employed workers have similar duties to those placed upon employers. Self-employed workers should not create risks to themselves or other people.

6 Under section 3 of the HSW Act, fairground and theme park controllers have a responsibility for the health and safety of non-employees, eg:

- members of the public;
- self-employed workers or contractors;
- volunteer workers;
- others who may be involved in the activities of the fairground and theme park.

7 Information may need to be provided so that these groups are not put at risk.

Duties of employees

8 While at work, employees have a legal duty under section 7 of the HSW Act to take reasonable care of themselves and other people. Employees must co-operate with their employer where safety is concerned.

Duties of people in control of premises or equipment

9 Many fairgrounds and theme parks have equipment or substances that they provide for people to use on site, eg lifting equipment, chemicals etc. Under section 4 of the HSW Act, each person who has any control of premises or equipment must take reasonable precautions to make sure that the location and equipment to be used there is safe and without risks to health. Also, where people come into the fairground and site to use it as a place of work, eg contractors, the people in control of the site should make sure, so far as is possible, that it is safe and does not present a health risk.

Duties of designers, manufacturers, importers or suppliers of fairground equipment

10 Section 6 of the HSW Act places duties on designers, manufacturers, importers and suppliers of fairground equipment. These duties include taking reasonable steps to ensure:

- fairground equipment is designed and manufactured to be safe when it is being built up and dismantled, operated and maintained; and
- suitable tests and checks have been carried out to prove this is the case; and
- there is adequate information provided with fairground equipment to allow a controller to build it, dismantle it, maintain it, inspect it and operate it safely; and
- they have a system for passing on safety updates on fairground equipment to people who have been supplied with it.

11 Anyone who wishes to design or manufacture a piece of fairground equipment should take reasonable steps to research and eliminate any risks to health and safety which the completed fairground equipment might pose, eg carry out research on the health effects of acceleration forces to make sure the ride operates within an acceptable limit.

12 If, as a designer, manufacturer supplier or importer, you install and/or erect a piece of fairground equipment, you need to take reasonable steps to ensure that it can then be used safely (including maintenance, inspection and operation).

13 The duties under section 6 only apply where there is a trade, business or other undertaking (for profit or not). They would not, for example, apply to a householder who lends out a bouncy castle to a next-door neighbour as a favour.

14 A piece of fairground equipment may be designed, manufactured, imported or supplied to, or for, someone else with a written agreement that this other person will take specified steps to ensure that the fairground equipment will be safe (as described in paragraphs 10–12 above). The agreement ‘shall have the effect of relieving the first mentioned person from the duty imposed to such extent as is reasonable having regard to the terms of the undertaking’ (section 6(8)). It should not, however, be assumed that all duties can be delegated to others. This exemption is a qualified one, and should be approached with caution and a clear understanding of what everyone involved has to do to ensure that the finished piece of fairground equipment is safe and without risks to health.

Duty not to misuse anything provided for the purposes of health and safety

15 Section 8 of the HSW Act places a duty on anyone who is at a fairground or theme park (including employees and members of the public) to behave sensibly and not to misuse or recklessly interfere with safety precautions. For example this would include the duty on passengers on a fairground ride not to damage ride restraints, and on operators and attendants not to defeat safety interlocking on devices.

Management of Health and Safety at Work Regulations 1999

16 The Management of Health and Safety at Work Regulations (MHSW Regulations) 1999[16] require employers and the self-employed to assess the risks arising from work activities to identify the control measures which need to be taken to comply with relevant health and safety legislation, eliminating risks where possible and reducing risk from those activities which remain. If a young person is employed then the assessment must examine a specific list of risks in light of the young person’s inexperience and immaturity.

17 The Regulations also require that employees must be given information about the risks to their health and safety identified by the assessment and protective and preventative measures that can be taken. This information must also identify emergency procedures in case of imminent danger and people nominated to implement those procedures. If the employer employs someone on a temporary contract, he or she must provide that person (and the employment agency who supplies such workers) with information on any special qualifications required for the worker if he or she needs to be able to carry the job out safely.

18 Regulation 11 requires that where two or more employers share a workplace they should:

- co-operate with each other to enable them to comply with statutory provisions;
- take reasonable steps to co-ordinate measures taken to comply with statutory provisions;
- take reasonable steps to inform each other of the risks to health and safety arising out of their work.

19 Regulation 12 requires employers to provide information to the employers of other people who are working in their undertaking. This information concerns:

- the risk to those people arising out of the undertaking;
- the measures taken to comply with the law.

Provision and Use of Work Equipment Regulations 1998

20 The Provision and Use of Work Equipment Regulations 1998 (PUWER)[17, 18] expand upon the general duties of the HSW Act and require that work equipment supplied to employees is suitable, correctly installed (if applicable), safe to use and used only by people who have received adequate training. Work equipment should be regularly maintained and, if necessary, inspected by a competent person to ensure that it remains safe to use. Work equipment, regardless of its age, should not cause a risk to health and safety.

21 PUWER makes more explicit the general duties already placed on an employer, self-employed person or someone with control to any extent of plant and operations to provide safe plant and equipment and to ensure employees are adequately trained in its use.

22 While the current industry-agreed examination and inspection scheme (ADIPS) will generally be sufficient to allow controllers to comply with their duty to have their devices adequately inspected, it is important for them to consider the other duties imposed by PUWER, for example:

- the duty to maintain a device in a safe condition;
- the duty to ensure the safety of dangerous parts of the ride and ride machinery; and
- the duty to provide information, instruction and training to employees and others who may be expected to use work equipment.

23 These duties apply to all equipment provided for use at work (within the scope of the Regulations), and not just to amusement devices.

Manual Handling Operations Regulations 1992 (as amended)

24 The Manual Handling Operations Regulations 1992 (as amended)[19, 20] apply to the transporting or supporting of loads by lifting, putting down, pushing, pulling, carrying and moving, either by hand or by bodily force. Employers must avoid, so far as is reasonably practicable, the need for their employees to undertake any manual handling operations which could lead to them being injured. Where this is not possible then employers need to consider the risks that arise from manual handling that could impact on the health and safety of their employees.

Lifting Operations and Lifting Equipment Regulations 1998

25 The Lifting Operations and Lifting Equipment Regulations (LOLER)[21, 22] replaced most of the old legislation on lifting and created a single set of regulations. Though PUWER applies to all work equipment including lifting equipment, LOLER applies over and above the general requirements of PUWER, in dealing with specific hazards/risks associated with lifting equipment and lifting operations.

26 It is the responsibility of dutyholders to ensure that any lifting operations they carry out, and any lifting equipment they operate, or provide for others to operate at work is both suitable and safe. Risk assessments should look at the risks to people being lifted by the equipment (if applicable) and to the risk to people by the operation of the equipment. All lifting operations should be properly planned, supervised and carried out safely.

27 In the fairground industry many devices require the use of lifting equipment for assembly and dismantling, for example trailer-mounted cranes, and passenger-carrying cars (eg found on big wheels and drop towers etc). Dutyholders are expected to have these thoroughly examined and inspected at intervals provided for in LOLER, or in accordance with an examination scheme. This examination is over and above any examinations and tests required to be carried out on fairground equipment under the current industry-agreed inspection scheme (ADIPS).

28 LOLER is unlikely to apply to a device itself, even those that have been described as ‘having a lifting element’, for example big wheels or drop towers or to the rams and pulley systems used to position a ride from the horizontal travelling position to its working position. LOLER may apply to parts of the ride used, for example, to lift carriages vertically from maintenance or storage areas (as seen with some larger fixed roller coaster rides).

Workplace (Health, Safety and Welfare) Regulations 1992

29 The Workplace (Health, Safety and Welfare) Regulations 1992[23] expand on the general duties of the HSW Act and cover a wide range of basic health, safety and welfare issues. They apply to most workplaces and place requirements on employers and people having (to any extent) control of workplaces. They cover areas such as: temperature; ventilation; lighting; cleanliness and waste materials; room dimensions and space; maintenance; floors and traffic routes; windows, doors, gates and walls; cleaning windows etc safely; escalators and moving walkways; toilet, washing, employees’ changing and clothes storage facilities; supply of fresh drinking water; and facilities for rest and eating meals.

Work at Height Regulations 2005

30 The Work at Height Regulations 2005[24] apply to all work at height (including work below ground) where there is a risk of a fall liable to cause personal injury. They impose duties relating to the organising and planning of work at height. See Appendix 4 for more information.

Personal Protective Equipment at Work Regulations 1992

31 The Personal Protective Equipment at Work Regulations 1992 (PPE Regulations)[25] expand on the general duties of the HSW Act and build on the MHSW Regulations.

32 PPE should always be the 'last resort' and should only be used to protect against the risk if engineering controls are not sufficient to reduce the risks to an acceptable level. In these circumstances, the Regulations require that an assessment be made to ensure that any PPE provided is suitable, compatible with other PPE required for the work, and is the last resort. Again, risks and hazards must be assessed and if engineering controls/systems will not overcome the hazards, suitable PPE must be provided. This can range from gloves to glasses, headgear to full-body options. In assessing the requirement for PPE, all parts of the body must be considered.

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR)

33 The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995[15] apply to events that arise out of, or in connection with work activities covered by the HSW Act. Where certain events specified in RIDDOR take place, eg the death of any person as a result of an accident, someone at work suffering a major injury, someone not at work being injured as a result of an accident and taken from the scene to a hospital (for example a member of the public injured on a fairground ride), or a dangerous occurrence as defined in RIDDOR under regulation 2(1), it must be reported and a record kept.

34 The following incidents on fairground equipment in use or under test are considered to be dangerous occurrences and reportable under RIDDOR:

- the failure of any load-bearing part;
- the failure of any part designed to support or restrain passengers;
- the derailment or the unintended collision of cars or trains.

Health and Safety (First Aid) Regulations 1981

35 The Health and Safety (First Aid) Regulations 1981[8, 9] require employers to provide adequate and appropriate equipment, facilities and personnel to enable first aid to be given to employees if they are injured or become ill at work.

36 You also need to consider whether trained first-aiders are needed, the items that should be included in their first-aid kit and whether a first-aid room is required.

37 The Regulations do not oblige you to provide first aid for members of the public, however, HSE and the industry trade associations strongly recommend that employers at fairgrounds and theme parks provide adequate first aid for members of the public.

Health and Safety (Consultation with Employees) Regulations 1996

38 The Health and Safety (Consultation with Employees) Regulations 1996[26] state that you should consult any employees (not in groups covered by trade union safety representatives) either directly or through elected representatives. If you decide to consult your employees through elected representatives, you must make the arrangements for an election. The Regulations outline general requirements for employee consultation and the rights and functions of elected representatives including the right to 'time off' with pay to carry out their functions and to undergo training.

Safety Representatives and Safety Committees Regulations 1977

39 Employees may be represented by safety representatives appointed from among the employees by a recognised union. The Safety Representatives and Safety Committees Regulations 1977[27] require you to consult safety representatives on arrangements that will enable them and employees to co-operate effectively in promoting and developing measures to ensure the health and safety of the employees, and to check the effectiveness of such measures. They set out the rights and functions of safety representatives, including the provision of information, facilities and assistance, and the right to take 'time off' with pay to carry out their functions and undergo training. If two or more safety representatives request a safety committee, one must be set up.

Health and Safety (Safety Signs and Signals) Regulations 1996

40 The Health and Safety (Safety Signs and Signals) Regulations 1996[28] require you to provide specific signs whenever there is a risk that has not been avoided or controlled by other means, eg by safe systems of work. There is no need to provide a sign if it would not help to reduce the risk, or where the risk is not significant. You will need to take into account, as part of the risk assessment, the provision of safety signs as an effective way to help control the risks, particularly in relation to emergency exits etc.

Regulatory Reform (Fire Safety) Order 2005

41 The Regulatory Reform (Fire Safety) Order 2005[29] came into force on 1 October 2006. It places emphasis on the prevention of fire in non-domestic premises, including the voluntary sector and self-employed people with premises separate from their homes.

42 The Fire Safety Order applies in England and Wales (Northern Ireland and Scotland have their own laws). It covers 'general fire precautions' and other fire safety issues which are needed to protect 'relevant people' in case of fire in and around most premises. The Order requires fire precautions to be put in place 'where necessary' and to the extent that it is reasonable and practicable in the circumstances of the case. Fire certificates have been abolished and will no longer have legal status.

43 Responsibility for complying with the Fire Safety Order will rest with the 'responsible person'. In a workplace, this is the employer if they have any control over the workplace. Otherwise it is the occupier if they use the premises for their business etc. If the occupier does not use the premises as such, then the responsible person would be the owner. In all other premises the person or people in control of the premises will be responsible. If there is more than one responsible person in any type of premises, they must take all reasonable steps to work with each other.

44 If you are the responsible person you will have to carry out a fire risk assessment which must focus on the safety in the event of a fire of all 'relevant people'. It should pay particular attention to those at special risk, such as the disabled and those with special needs, and must include consideration of any dangerous substances present on the premises. Your fire risk assessment will help you identify risks that can be removed or reduced and to decide the nature and the extent of the general precautions you need to take to protect people against the fire risk that remains.

45 If you employ more than five people you must record the significant findings of the assessment.

46 *A short guide to making your premises safe from fire*[30] provides entry level guidance on how to make sure you are meeting the requirements of the Regulatory Reform (Fire Safety) Order 2005. Visit www.communities.gov.uk for more details. Also see Appendix 6 of this guidance.

Control of Noise at Work Regulations 2005

47 The Control of Noise at Work Regulations 2005[31, 32] require employers to prevent or reduce the risks to health and safety from exposure to noise at work. They require you as an employer to:

- assess the risks to employees from exposure to noise at work;
- take action to reduce the noise exposures that produce those risks;
- take specific actions at the action levels and make sure the limits for noise exposure are not exceeded;
- provide employees with hearing protection if you cannot reduce the noise exposure enough by using other methods;
- provide your employees with information, instruction and training;
- carry out health surveillance where there is a risk to health.

48 As a rough guide, noise is likely to be at a hazardous level if people have to shout or have difficulty being heard clearly by someone about 2 m away. If there is a likely noise hazard, you will need to arrange for a competent person to complete a noise assessment. This will identify the daily individual noise exposure for each of your employees who might be at risk of over-exposure, and will provide information to help you decide what you will do to control the noise exposure. This should be the first step for you in developing an action plan for introducing noise-control measures. Hearing protection for employees should be provided as a last resort.

Control of Substances Hazardous to Health Regulations 2002 (as amended)

49 The Control of Substances Hazardous to Health Regulations 2002 (COSHH) (as amended)[33] require a COSHH assessment to be carried out to protect employees and visitors against health risks from hazardous substances used or generated. Hazardous substances can be biological agents, dusts, substances with exposure limits, or substances highlighted as hazardous in the safety data sheet.

50 The Regulations require you to take the following steps:

- assess the risks from hazardous substances;
- decide what precautions are required;
- prevent or adequately control exposure;
- demonstrate that you have achieved adequate control;
- ensure that control measures are used and maintained;
- monitor the exposure;
- carry out appropriate health surveillance;
- prepare plans and procedures to deal with accidents etc;
- ensure employees are properly informed, trained and supervised.

Electricity at Work Regulations 1989

51 The Electricity at Work Regulations 1989[34] impose detailed requirements on employers in control of an electrical system to ensure that the system is safe. These requirements are concerned with the design of systems covering matters such as earthing and bonding, the means for protecting against excess of current, insulation and placing of conductors, means of isolation, and fault withstand capability etc.

52 The Regulations also require all electrical systems to be maintained to prevent, so far as is reasonably practicable, any danger, but maintenance should be carried out so that it does not give rise to danger. The Institution of Electrical Engineers publishes guidance on inspection and testing of low-voltage electrical installations and equipment.

53 The Regulations also require people working on electrical systems where danger may arise to be competent or to be supervised. Helpful advice on safe systems of work on electrical systems is published in HSE's guidance book HSG85 *Electricity at work: Safe working practices*.[35]

54 The EAW Regulations should not be confused with BS 7671 *Requirements for electrical installations*,[36] previously, but still commonly, known as the IEE Wiring Regulations. This has the status of a code of practice, so that compliance with it is likely to lead to compliance with the relevant parts of the EAW Regulations. However whereas BS 7671 deals with the safety of electrical power distribution systems, it does not cover safe working practices on electrical systems and for that you must refer to these Regulations.

Disability Discrimination Act 1995

55 The Disability Discrimination Act 1995[14] gives disabled people rights to access your rides and you may have to make 'reasonable adjustments' to help. You should know what safety precautions are needed to allow the public to use your device safely (use of restraints, hand and foot bracing points, information and instructions etc), and where you think a disabled person may have problems complying, consider whether there are any adjustments that you can make to enable them to use the ride safely.

56 You may, however, be able to justify less favourable treatment of a disabled person and not making an adjustment for a disabled person, but only if this is necessary to protect people's health and safety, eg other customers, the disabled person themselves or the operator (see shaded example). You will need to consider the unique nature of your amusement park or fairground and the individual circumstances of your client. You are likely to discriminate if you have a 'blanket' rule that treats disabled people differently, eg if you ban all disabled people from your rides.

57 Avoid making assumptions and seek to involve, where you can, disabled customers or those supporting them. They are likely to have thought about the suitability of rides beforehand and together you can make an informed decision.

Example
A fairground operator refuses to allow a person with multiple sclerosis onto a physically demanding, high-speed ride. Because of her disability, the disabled person uses walking sticks and cannot stand without help. The ride requires users to brace themselves using the strength in their legs. The refusal is based on real concerns for the health and safety of the disabled person and other users of the ride. This is likely to be justified.

58 Find out more from the Disability Rights Commission at www.drc.gov.uk and from HSE's website www.hse.gov.uk.

Health and Safety (Enforcing Authority) Regulations 1998

59 The Health and Safety (Enforcing Authority) Regulations 1998[37] allocate premises to either the local authority or the Health and Safety Executive for the purposes of enforcing relevant health and safety legislation. In general, this means that travelling fairgrounds and theme parks will fall to HSE, and inflatable devices, bungee and go-karts will fall to the local authority for the purposes of inspection (HSE will always be the enforcing authority for section 6 of the HSW Act). Where inflatable devices and go-karts are found within the overall provision of a theme park or travelling fair, HSE will normally be the enforcing authority.

60 The regulations allow for local arrangements to be reached between HSE and a local authority that transfer enforcement responsibility for a particular dutyholder from one authority to the other.

Construction (Design and Management) Regulations 2007

61 The Construction (Design and Management) Regulations 2007[38] apply to specified construction activities and place duties on clients, designers and those involved in the construction work. They do not apply to the erection and dismantling of marquees, tents or the erection and dismantling of travelling fairground rides. For the most part they will not apply to the installation of rides intended to be permanently installed (eg at amusement parks) as fairground rides are not considered to be structures, as defined in the Regulations. However the Regulations may apply to construction work that accompanies the installation or dismantling of such devices, or is carried out within a theme park (construction of fixed structures such as offices, cafés etc).

Appendix 2
Risk assessments to establish maturity of design for fairground rides

Introduction

1 The following information may help with preparing a suitable maturity risk assessment and checking that existing ones are suitable. It includes advice on when an assessment would be appropriate and how it could be carried out.

2 Section 6 of the HSW Act (as amended) puts very specific responsibilities on the designers, manufacturers, importers and suppliers of fairground equipment to ensure that devices are designed and constructed to be as safe as far as is reasonably practicable.

3 The series of pre-use inspections (design review, assessment of conformity to design and initial test) described in this guidance, if completed diligently, will allow for compliance with the HSW Act section 6 duty. These pre-use inspections form part of the Amusement Devices Inspection Procedures Scheme (ADIPS).

4 When ADIPS was introduced in October 1997, it was recognised that there would be a significant number of rides which had not been subjected to the initial pre-use inspections, but which were well-designed and constructed. In these cases the manufacturer may have complied with section 6 of the HSW Act in a different way and it was clear that interim arrangements would be required to allow the ADIPS scheme to function and to allow Declarations of Operational Compliance (DOCs) to be issued in the absence of information on initial inspection.

5 These interim arrangements only applied to devices that existed in the UK **before October 1997**. They introduced the concept of a ride that was of a mature design. This means there is sufficient relevant information available to determine that the ride design has a history of safe operation and has therefore stood the test of time.

Maturity risk assessment

6 The responsibility for producing a maturity risk assessment lies with the controller of a device. Controllers cannot claim maturity for an older ride by right. Just because a ride is old, it does not automatically follow that it is mature. When a device has been declared mature, this should be justified by a risk assessment that supports this conclusion.

7 Ride controllers can establish that a ride is well-designed and constructed in the absence of pre-use inspection information by undertaking a maturity risk assessment. Such an assessment is in addition to, and separate from, the operational risk assessment required for all rides. Ride controllers may use others to help with this process, eg inspection bodies may be able to help in areas where they are competent, such as mechanical, structural, or electrical aspects.

8 While the history of other rides is useful supporting evidence, controllers should be wary of placing too much emphasis on such information unless they are certain that the other rides are identical in design and manufacture. In theory it is possible to build a new ride to an established design, then claim maturity for the device. However, unless it can be demonstrated that the design **and** manufacture were identical, it cannot be declared to be mature.

When is a maturity risk assessment appropriate?

9 The following issues should be considered:

- if the ride has a relevant design review and initial inspections then it does **not** need a maturity assessment;
- if the ride was not in existence in the UK before October 1997 it **cannot** be considered mature;
- to carry out a satisfactory maturity risk assessment a controller will need at least five years of relevant history for the ride under consideration. (The required history is described below.) Although the figure of five years is given as guidance and will need to be considered in the context of the risk assessment, it is unlikely that a ride with less than five years' history could be declared mature;
- a ride which has had very little use in the last five years may require more than five years' history to demonstrate that it is capable of operating safely over a sustained period;
- ride histories are best presented in written form;
- a controller must know whether the ride or any part of the ride has been modified. If any of the safety-critical parts of the ride have been modified since October 1997, a partial design review of the ride which covers the modified part (and any consequences it may have on the safe operation of the ride as a whole) is required;
- modifications that took place before October 1997 may have sufficient history of safe operation to be considered mature. The period of five years is given as a guide. If the rest of the ride is unmodified it could be the subject of a maturity risk assessment as long as the other criteria are met;
- if the whole ride has been modified, a complete design review is required and maturity assessment is not appropriate.

Documents required for a maturity risk assessment

10 Before a controller undertakes a maturity risk assessment they will need the following documents and information:

- HSG175 (this book);
- the accident history for the particular ride and the class of ride (as far as possible), detailing accidents arising from the ride design (for at least five years). Accident history for classes of ride may sometimes be difficult to obtain, however, inspection bodies, trade organisations etc may be able to help;
- details of modifications to safety-critical parts;
- the operational risk assessment;
- maintenance records (including repairs) and records of previous inspection including non-destructive testing for at least five years. These are important because they may indicate areas of concern with the design. They are also important because they indicate the parameters within which the device should work and which will have contributed to its record of safe operation;
- details of ease of accessibility and frequency of testing and inspection of safety-critical parts. If safety-critical parts are inaccessible then it may not be possible to spot emerging problems at an early stage and it may be that they have not been inspected thoroughly over the years. Under these circumstances it is likely that a partial design review will be a more appropriate method to decide that these parts are safe;
- other information, eg HSE guidance, National Association for Leisure Industry Certification (NAFLIC) bulletins, manufacturers' information etc which relates to the class of ride and any problems with design;
- an operations manual. This is an essential aid to the maturity assessment. It is unlikely that maturity could be established without one, as all of the evidence required to support the conclusions of the assessment should be contained within such a manual. Further information on operations manuals is in Appendix 3.

Content of a maturity risk assessment

11 Controllers will need to have identified that:

- there is a hazard from injury due to the failure of a safety-critical part as a result of poor design;
- people at risk may be riders, operators or bystanders;
- the principal control measure, for the purposes of this assessment, is the integrity of the design and construction which has reduced risk to an acceptable level. The evidence that the design is adequate is based on a number of years of safe operation and should be contained in the documents listed above;
- the design and construction must be capable of withstanding all types of failure including corrosion, wear and fatigue and the evidence for each must be considered;
- the ability of the design to withstand deterioration is dependent on the correct operation of the ride coupled with adequate maintenance and inspection.

12 The findings of the assessment must be recorded in a suitable form to allow controllers to support the conclusion that a ride is mature. The maturity assessment should be appended to the operations manual.

13 If it cannot be established that the ride is mature, then the necessary design review(s) should have been completed by March 2004.

Checklist for controllers

14 These questions should help controllers assess whether or not a maturity risk assessment is appropriate for their device, and whether they have adequate information to complete it satisfactorily:

- Does the device have evidence of initial inspections?
- Was the device in the UK before October 1997?
- Have you identified the safety-critical parts with the help of an inspection body?
- Have any safety-critical parts of the ride been modified since 1997? (If yes, consider a partial design review of new parts and consider maturity for older parts.)
- Has the ride been used continuously and do you have at least five years' history of operation (in your operations manual)?
- Does this history indicate the ride has operated safely for at least five years?
- Do you have maintenance records, details of repairs and details of past examinations for at least five years?
- Do these indicate that the design of any part of the ride may have been a cause for concern taking into account foreseeable modes of failure and the existing control measures (including inspection and maintenance)?
- Are all of the safety-critical parts of the ride accessible? (If no, what measures have been taken to ensure the continuing integrity of these safety-related parts?)
- Do you have the accident history for this class of ride?
- Does this indicate that there might be a problem which might affect your ride?
- Do you have access to HSG175, other relevant HSE guidance and industry guidance such as NAFLIC bulletins for this type of ride?
- Do these documents indicate that there might be a problem which might affect your ride?
- Does the operating manual contain other details required in HSG175 Appendix 3?
- Do these indicate how the ride should be operated, inspected and maintained?

15 Does the above information, when considered as a whole, demonstrate that the ride has an adequate history of safe operation which indicates that the risk of injury arising from a failure of design is at an acceptable level?

Appendix 3
The operations manual and other information for the safe operation of an amusement device

Information requirements

1 The successful operation, maintenance and inspection of any amusement device will require access to information by different individuals at different times, for example:

- operators may need information about the safe way to operate the ride, emergency procedures and the periodic checks that need to be done before the ride is operated;
- maintenance fitters may need information about the schedules of inspection to allow them to carry out safety checks;
- registered inspection bodies may need access to design review information and previous in-service inspections; and
- regulatory inspectors (eg from HSE) may wish to see records of training and records of scheduled inspections.

2 The controller should ensure that each amusement device has adequate information available to allow it to be safely operated, maintained and inspected.

3 Some of this information will need to be kept with the ride for ease of reference. Other sources of information may be complex and bulky and not necessarily required to be kept with the ride, but in a location where they can be retrieved easily when required.

4 The types of information that are likely to be complex and bulky are the records of design and manufacture, and the details of the pre-use inspections. It is not always necessary that this information needs to be kept with the ride as long as it is readily available to the controller when required, eg when needed by an inspection body.

5 The documents and information that need to accompany any amusement device should be kept in an operations manual and be with the device when it is operational. This should include all the necessary documentation relating to the operation, maintenance, and in-service inspection of the ride.

6 Examples of documents that that should normally be kept with the ride include:

- the Declaration of Operational Compliance (DOC);
- all the necessary risk assessments;
- operator instructions, including emergency procedures;
- records of attendants who are allowed to operate the ride;
- details of the daily and periodic inspections;
- schedules for the in-service inspection, including schedules for the mechanical, hydraulic, electrical, pneumatic and non-destructive testing of the device as required;

- details of safety-critical modifications. This should include the following:
  - details of design review of all safety-critical modifications which have caused the device to differ from the original specification;
  - details of assessment of conformity to design of all safety-critical modifications, as above;
  - details of initial test of safety-critical modifications, as above;
  - confirmation of witnessing and verification by inspection bodies of initial tests of the above safety-critical modifications.

7 The extent of this information will depend on the nature of the device, and the nature of the modification carried out.

Information on transport, installation, erection and dismantling

8 The operations manual should contain information on transport, installation, erection and dismantling, including:

- diagrams to show the correct assembly of the component parts;
- a key to the identification of non-interchangeable parts;
- information on the correct use of any special equipment required for assembly;
- details of the weight distribution and recommended packing points, together with the maximum applied load at each point and any foundations required;
- diagrams and drawings of the safe means of erecting and dismantling the ride, along with any required clearance distances necessary for safe operation;
- procedures for setting up and dismantling the device correctly including, where relevant, details of:
  - any safe systems of work required, along with details of personal protective equipment needed;
  - emergency rescue plans (eg for working at height);
  - advice on ground or foundation preparation;
  - order of assembly/disassembly of component parts;
  - any temporary measures needed to support a partially completed device;
  - torque settings essential to the safety of screws or bolts;
  - any procedures needed to prevent or relieve stress concentration during assembly/dismantling;
  - jacking and packing points and procedures, including selection of materials, load spreading and ballasting where relevant;
  - levelling and out-of-level tolerances;
  - barriers, fencing etc;
  - mechanical and electrical power requirements;
  - correct methods for connecting electrical equipment to the power supply;
  - grounding for lightning protection;
- any checks or testing needed to make sure the device has been assembled correctly and is functioning in the intended manner.

Information on safe use

9 The manual needs to contain information on safe use, including:

- a description of the normal functioning of the device (including the function and motion of the major components);
- the normal safe operating procedure (including the functions and responsibilities of the operator and attendants);
- details of operating speeds. The maximum or limiting speed should not be based solely on the forces that the device can withstand but should also take account of the need to prevent injury to users;

- information on loading which should specify:
  - the maximum working loads;
  - maximum passenger numbers;
  - permissible out-of-balance loading;
  - order of passenger loading;
- limitations to use, eg passenger dimension (size, weight), medical condition, adverse environmental conditions (especially wind speed);
- details of any passenger-containment system and guidance on its use;
- information on relative positioning of passengers in the same car;
- potentially dangerous passenger behaviour;
- detailed explanation of the controls and their function;
- safe passenger access;
- limitations required to prevent static overload in waiting areas;
- safe and unsafe operating practices;
- faults and fault finding, including indications of malfunction and the action to be taken;
- emergency procedures, including evacuation.

Instructions and guidance on any maintenance and inspection

10 The information needs to cover:

- components which require regular lubrication including information on suitable lubricants and the frequency required;
- components which require regular replacement and the period between replacement;
- components which require inspection for wear, correct setting etc together with details of the correct settings and allowable tolerances;
- electrical equipment together with any checks to be done by the user and details of safe isolation procedures;
- maintenance and testing of controls and interlocks.

11 The controller should add any other relevant information gained from operating the device.

12 The manual needs to be in the controller's first language. The controller should also take into account the needs of any foreign workers employed and ensure they are provided with sufficient information to allow them to work safely. It is important that the manual is 'user-friendly' and gives clear information on how the device can be used safely.

Appendix 4
Working at height

Work at Height Regulations 2005

1 The Work at Height Regulations 2005 apply to all work at height where there is a risk of a fall liable to cause personal injury. They place duties on employers, the self-employed, and any person who controls the work of others, eg a ride controller who may contract someone to work at height.

2 As a dutyholder you must ensure:

- all work at height is properly planned and organised;
- those involved in work at height are competent;
- the risks from work at height are assessed and appropriate work equipment is selected and used;
- the risks from fragile surfaces are properly controlled; and
- equipment for work at height is properly inspected and maintained.

3 There is a simple hierarchy for managing and selecting equipment for work at height. You must:

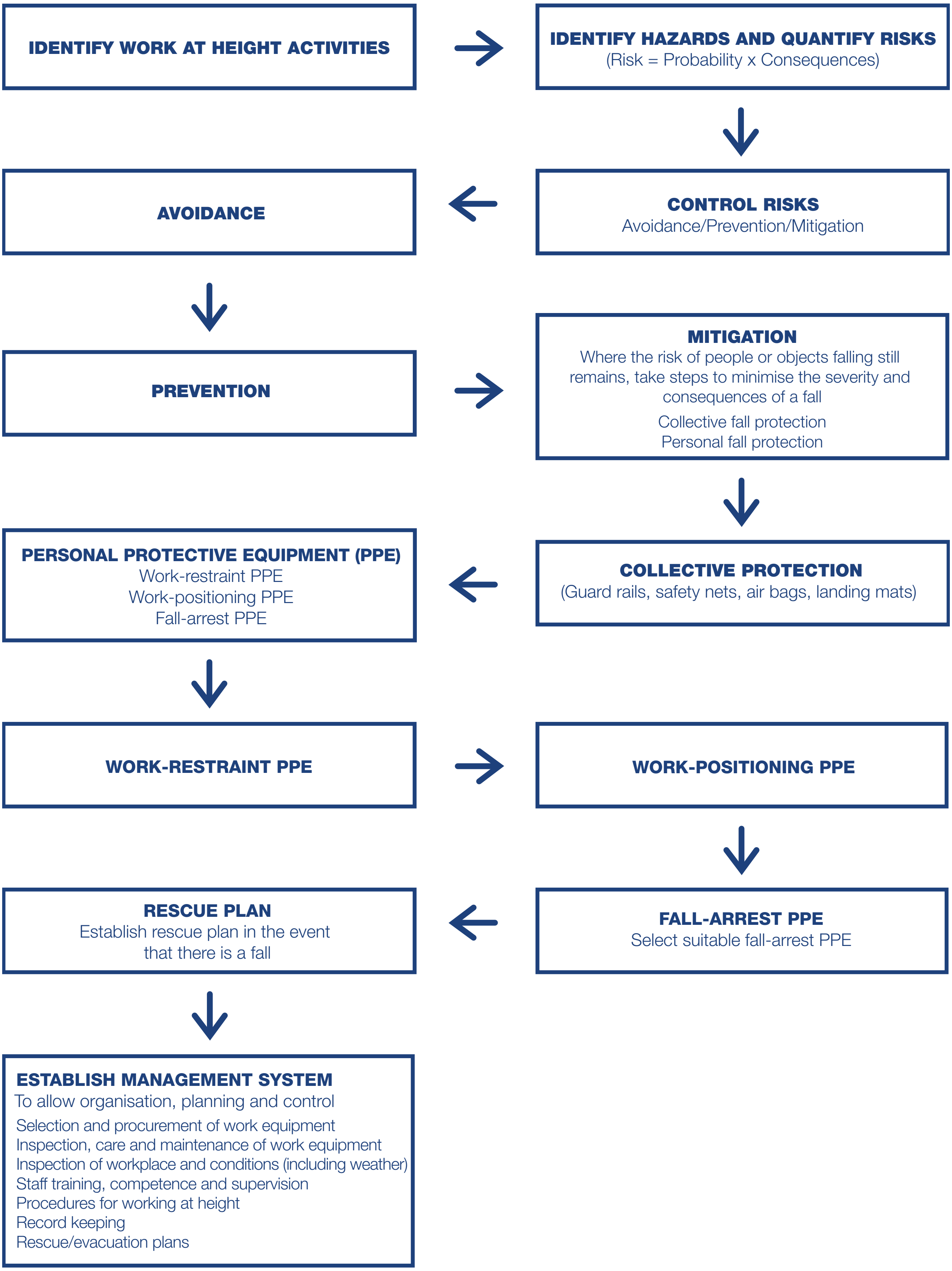
- avoid work at height where possible;
- use work equipment or other measures to prevent falls where you cannot avoid working at height; and
- where you cannot eliminate the risk of a fall, use work equipment or other measures to minimise the distance and consequences of a fall should one occur.

4 There are occasions when work at height is required in the fairground industry, for example during:

- assembly and dismantling of devices;
- commissioning;
- maintenance;
- inspection;
- breakdown repair;
- emergency evacuation.

5 Flow Chart 1 is intended to help dutyholders within the fairground sector who may either work at height themselves, have employees who as part of their duties may have to work at height, or control the work of others working at height.

Flow chart 1 Risk assessment process for working at heights illustrating the general risk assessment process adopting the safe working at heights hierarchy approach of avoidance, prevention and mitigation.



Appendix 5
Non-destructive testing

General principles

1 Non-destructive testing (NDT) is the testing of materials, for surface or internal flaws or metallurgical condition, without interfering in any way with the integrity of the material or its suitability for service. It may be performed during manufacture as part of quality assurance procedures to make sure that a structure or component is fit for use, free of significant defects and conforms to the design specification. It is also used as part of in-service annual inspection to determine whether structures or components continue to be fit for service.

Written schedule of NDT

2 The controller of a device should have a written schedule of inspection for NDT available that specifies the frequency of in-service NDT that is required (this can be measured in either time and/or ride cycles as appropriate), the type of NDT to be used, the location and defect acceptance criteria. It should have been drawn up by a suitably qualified mechanical/structural engineer along with a person qualified in the NDT techniques to be used.

3 The mechanical/structural engineer should identify the parts of the device that require testing, the frequency of inspection and the extent of dismantling required to gain access to them.

4 The NDT practitioner should specify the appropriate test methods and techniques to be used. These must be reliable and repeatable, so that results can, if necessary, be compared to previous results.

5 The types, size, locations and orientations of defect indications should be referred to the relevant inspection body for a decision on the action to be taken, eg repair, replace or allow continued use.

Report of NDT

6 In this document the NDT practitioner provides a record for the inspection body and controller of the parts tested and the results obtained. The inspection body will need to assess these results when preparing the report of in-service annual inspection. An NDT report needs to include:

- confirmation that the inspection has followed the written schedule and any further tests carried out;
- the date of inspection;
- the inspector’s name and their qualifications relevant to the type of inspection;
- the parts or elements examined which form any sample;
- details of the NDT methods, techniques and procedures used;
- the results of inspection.

7 The controllers should keep copies of NDT reports for the life of the device.

8 When assessing the reports, the inspection body should:

- be competent to distinguish between original manufacturing flaws and flaws which have developed during use. Having the results of previous NDT in the operations manual can be a valuable reference;
- be competent to distinguish between significant and insignificant indications. This will require, for example, a sufficient understanding of:
  - the manufacturing methods used and the types of flaws likely to be introduced during manufacture;
  - the significance of the type, size and orientation of the flaw with regard to the geometry, material and loading of the component;
  - the purpose and limitations of the NDT method used.

9 The inspection body may need to seek specialist advice if necessary.

Qualifications and competence

10 Every NDT practitioner should be competent to do the test and to accurately report the results.

11 There are three main qualifications commonly used in this country: ASNT (American Society for Non-destructive Testing); PCN (Personal Certification in Non-destructive Testing) and welding inspector.

12 A person qualified under ASNT is able to carry out a certain type of inspection which is specified in a written procedure. They are not normally qualified outside that procedure. Before a person claiming compliance with ASNT is engaged to do NDT work, enquiries should be made about the scheme and syllabus of that person's training and whether it is within the scope required to inspect an amusement device.

13 PCN is a recognised world-wide scheme. A certificate issued under the scheme is valid for a maximum of five years and may be withdrawn at any time by the issuing authority. The scheme has three levels of competence:

- **Level 1:** an inspector requires supervision by a person qualified at least to Level 2.
- **Level 2:** the main level of practitioner. They can prepare written instructions from appropriate NDT standards and evaluate the results.
- **Level 3:** an inspector competent to write and validate NDT procedures usually needs five years' experience.

14 A welding inspector is qualified to inspect the welding process as well as the finished weld. A person holding this qualification can test existing welds and inspect any remedial work in progress as well as the finished result. However, in the absence of other qualifications, a welding inspector may not be competent to undertake other forms of NDT.

Typical defects

15 Typical defects encountered in testing of amusement devices are:

- in-service-induced fatigue cracking;
- corrosion;
- manufacturing-induced defects.

Typical test areas

16 Typical test areas are:

- safety-critical welds;
- weld repairs;
- axles;
- bolts and fixings;
- glass-reinforced plastic (GRP) laminates.

Typical NDT techniques used to test amusement devices

Visual and optical inspection

17 Visual inspection involves looking for defects. Special tools such as magnifying glasses, mirrors, or borescopes can be used to enable access and inspect in greater detail the subject area. This technique can be useful as part of an overall mechanical inspection of an amusement device, but will not normally be sufficient to complete an adequate NDT inspection of most amusement devices.

Dye penetrant (DP)

18 Dye penetrant requires careful preparation and pre-cleaning to ensure that there are no contaminants in the crack that would prevent the penetrant being drawn into it. The parts of the device to be examined are painted or sprayed with a visible or fluorescent dye solution and left for a period of time (normally around 15 minutes). The excess is removed and a developer agent (frequently white chalk) is applied. This acts as a 'blotter' and draws the trapped penetrant out of defects that are open to the surface. With visible dyes, vivid colour contrasts are used between the penetrant and developer to make the defect easy to see. With fluorescent dyes, ultraviolet light is used to make the defect visible.

19 It is relatively simple to carry out and it is useful in detecting surface-breaking defects in non-ferromagnetic parts which cannot be tested using magnetic particle inspection (MPI). A disadvantage is that it is restricted to surface-breaking cracks, and the presence of paint on the test piece can adversely affect detection of defects.

Magnetic particle inspection (MPI)

20 Magnetic particle inspection (MPI) is a method used for defect detection of surface or near-surface-breaking defects. These distort the magnetic field and concentrate iron particles near imperfections, giving a visual indication of the flaw. This test is carried out by inducing a magnetic field in a ferromagnetic material and then dusting the surface with iron particles (either dry or in suspension). The technique is used widely in weld testing and inspection.

21 It is important to remember that the component being inspected must be made of a ferromagnetic material such as iron, nickel, cobalt, or some of their alloys. This is because the component must be capable of being magnetised to a level that will allow the inspection to be effective.

22 With magnetic particle inspection the flaw indications generally look like the actual flaw. Cracks on the surface of the part appear as sharp lines that follow the path of the crack. It is another relatively simple process, but with the disadvantages that it can only detect surface or near-surface defects and can only be used on ferromagnetic material. Unbroken, tightly-adherent paint layers up to about 0.05 mm (50 microns) do not normally impair detection sensitivity. See EN 9934-1[39] for further details.

Eddy current

23 Eddy current (EC) is used for the detection of surface or subsurface flaws – the paint does not need to be removed. It can only detect cracks up to 2 mm deep. Eddy currents can be produced in any electrically conducting material that is subjected to an alternating magnetic field. The field is generated by passing an alternating current through a coil, which is wrapped round a ferrite rod and placed on the surface to be examined. When a crack, for example, occurs in the product surface, the eddy currents must travel further around the crack and this is detected by a change in the impedance measured in the coil.

Ultrasonic (UT)

24 High-frequency sound waves are passed into the test object and reflections (echoes) are returned to a receiver from internal imperfections or from the part's geometrical surfaces. This technique is widely used in the fairground industry and when used correctly can be a highly efficient method of detecting subsurface imperfections. It is important that the interpretation of results is carried out thoroughly. As with all other test techniques it has limitations, for example:

- if the test area is rough, irregular in shape or small, it can be difficult to detect defects;
- cast iron and other coarse-grained materials are difficult to inspect due to low sound transmission and high signal noise;
- linear defects oriented parallel to the sound beam may go undetected.

Radiography

25 Radiographic testing (RT) is used to detect internal defects in metals. X-rays or gamma rays are transmitted through the material and are differentially absorbed by the material through which they pass. An image is produced on a photographic film placed on the opposite side. It requires access to both sides of the weld. It is not suitable for surface-breaking defect detection and does not give an indication of the depth of a defect from the surface. While it has been shown that radiography can be used successfully by suitably trained operatives on certain parts of amusement devices (for example welds which cannot be examined using UT that are hidden underneath strengthening plates) the expense and detailed procedures that are required mean that it is not commonly used.

Appendix 6
Fire precautions and gas safety

Introduction

1 This appendix covers both fixed and temporary sites. It gives practical advice on fire safety, but does not provide an authoritative interpretation of fire safety legislation. Organisers and controllers may need to liaise with the appropriate authorities for further information on how to comply with legal requirements. Guidance on fire safety is given in *Fire safety risk assessment – Small and medium places of assembly* and in *Fire safety risk assessment – Open air events and venues* both available to download at www.communities.gov.uk.[29]

2 Typical fire hazards in fairground and amusement parks with some of the practical precautions are shown in Table 3. As well as the fire hazards themselves, the organiser may need to consider what could affect the spread of fire, such as:

- site layout, particularly separation distances between structures;
- features within structures, such as lift shafts, ducts, flues, openings in floors or walls, combustible linings;
- local environmental factors, particularly those that affect wind speed or direction, eg through channelling effects;
- distance from surrounding buildings (in street fairs it is important to consider how a fire in a neighbouring building could affect the fair and vice versa).

3 As well as the precautions in Table 3, other general precautions are:

- remove materials which are flammable or give off toxic fumes in fires and replace them with less hazardous ones;
- provide fire warning arrangements;
- provide means of escape;
- provide appropriate fire-fighting equipment and training in how to use it;
- make sure that staff are adequately trained in general fire precautions and good housekeeping and know what to do in case of fire (this should include practical exercises).

Table 3 Typical fire hazards and some practical precautions

Fire hazard	Practical precautions
1 Presence of combustible materials, in particular:	Keep combustible materials to a minimum and where possible secure.
(a) Structures	Make sure structures and their furnishings have appropriate fire resistance.
(b) Fuels, including flammable liquids and LPG	■ Do not store more fuel than you need or are allowed to. ■ Keep flammable liquids, eg petrol, in suitable closed containers, clearly marked to show the contents. ■ Store the containers safely and secured against unauthorised access (not under lorries or near cables or other electrical equipment).
(c) Rubbish	■ Provide fire-resistant rubbish containers and empty them regularly. ■ Arrange regular collection of rubbish left on the ground. ■ If you cannot dispose of rubbish immediately, store it away from sources of ignition, other flammable materials etc and keep it secure.
(d) Vegetation	■ Keep grass short and LPG stores free of weeds. ■ Be prepared to damp down vegetation in dry weather.
2 Misuse of equipment using solid, liquid or gas fuels (eg generators, cookers, heaters) including:	Check regularly the condition and use of equipment.
(a) Lack of maintenance	Make sure it is maintained according to the manufacturer's instructions. You may need to bring in a competent person to check and maintain it. (See paragraphs 51–61 of this appendix, regarding gas safety.)
(b) Dangerous location	■ Do not use naked flames near combustible materials. ■ Do not use naked flames in structures (especially tents and marquees) when the public are present. If used at other times, keep the appliance under constant supervision and remove it to a safe place with the flame extinguished before admitting the public.
(c) Obstructed ventilation	Check that there is adequate ventilation to: ■ allow fuels to burn properly and combustion products to escape safely;
(d) Refuelling	Only refill fuel tanks or change gas cylinders in the open air or in a well-ventilated area away from sources of ignition. Never refuel when an engine is running or an appliance is lit.
(e) Reigniting	Never attempt to reignite a Salamander-type waste oil heater while the heater is hot.
3 Misuse of electrical equipment, including: (a) Inadequate installation, poorly routed cables etc (b) Lack of maintenance (c) Unauthorised and temporary repairs, wrong cables, connectors, fuses etc (d) Overloading (e) Equipment left on when not in use	Regular visual checks with inspection and testing by a competent person as appropriate.

Table 3 Typical fire hazards and some practical precautions

Fire hazard	Practical precautions
4 Smoking and misuse of smoking materials, eg matches	■ Prohibit smoking in hazardous areas, particularly near fuels and in tented, inflatable or similar structures. ■ Provide ashtrays etc where smoking is permitted.
5 Actions of contractors and maintenance workers, eg hazards arising from welding spools and hot metal	■ Make clear what they should and should not do. ■ Make them aware of any particular fire risks and your fire safety policy and precautions. ■ Monitor their work regularly.
6 Unauthorised access/arson	■ Make all staff aware of the importance of security. ■ Keep flammable materials to a minimum and as secure as possible. ■ Make regular checks of the site.

Note: This list is not exhaustive, but should help you identify the main hazards and precautions. The local fire and rescue service can give much more detailed advice, particularly on matters such as the safe storage of flammable materials.

4 The assessment should be monitored regularly to make sure that the fire safety arrangements remain relevant. It should be reviewed if there is a significant change in:

- work activity;
- fire risk, eg changes in the materials used or the way they are stored;
- number of people (staff or public) at risk;
- site or structural layouts affecting the means of escape or other fire safety arrangements or if building work is being considered.

5 A new assessment should be made for every new site to make sure that fire precautions and escape routes will be adequate. Similarly, if a permanent site is taken over by a new organiser a new fire risk assessment should be made as soon as possible.

Emergency plan

6 An emergency plan should be prepared from the findings of the risk assessment. It should be kept on site, be available for inspection and include:

- the action to be taken by staff in the event of fire, including those who have specific fire safety functions, eg nominated deputies, fire marshals etc;
- the arrangements for any people at particular risk, eg builders, contractors, maintenance workers, members of the public, people with disabilities;
- any specific arrangements for parts of the site with high fire risk;
- evacuation procedures for everyone on site, including details of escape routes;
- arrangements for calling the fire brigade and informing them of any special hazards.

7 The organiser may find it helpful to include a simple sketch showing, where relevant:

- essential features such as the layout of the site, escape routes (including those from any structures etc);
- the number, type and location of fire-fighting equipment available, eg extinguishers, hose reels, fire blankets etc;
- the location of:
  - manually-operated fire-alarm call points, automatic fire-detector heads and control equipment for the fire alarm;
  - any automatic fire-fighting system and sprinkler-control valve;
  - the main electrical supply point, the main water shut-off valve and (where appropriate) the main gas or oil shut-off valves;
  - any special hazards or highly flammable substances.

8 After the emergency plan has been prepared, prominent notices should be displayed on site giving clear instructions about what to do in case of fire. They should describe how to raise the alarm and give the location of the assembly points to which people escaping from the site should report.

9 On small sites, the plan can take the form of a simple fire action notice which should be posted where staff can read it and become familiar with it. For example:

FIRE ACTION	
If you discover a fire:	
1	Sound the alarm
2	Call the fire brigade
3	Fight the fire if safe to do so
On hearing the fire alarm, you should:	
4	Follow the emergency plan
5	Report to your assembly point

10 The organiser may also wish to draw up a contingency plan in case the site is damaged by fire.

Information and training

11 Fire safety arrangements should:

- be brought to the attention of new staff and contractors;
- remain familiar to existing staff and contractors;
- be tested by fire drills, any problems remedied, and the results recorded.

Site layout

12 When planning a fair, the organiser needs to consult the local fire authority and consider the following fire safety factors:

- safe access in and out of the site for fire engines and for the public (including people with disabilities);
- risks relating to the spread of fire (see paragraph 2 of this appendix);
- means of calling the emergency services (eg telephones);
- the availability of mains services (particularly water for fighting fire);
- the slope or unevenness of the ground;
- the availability of car parking (so that it can be properly arranged to avoid obstructing emergency access).

13 Where there are more than eight amusement devices designed for use by adults, it is recommended that the organiser should prepare a sketch plan showing the position of attractions, vehicles and caravans (see Section E). The sketch used for the emergency plan (see paragraph 6 of this Appendix) could be used. The plan should be kept up to date and be available to the fire authority before the fair opens.

Access for fire engines

14 Access routes to and within the site should be checked to make sure that they can take the maximum weight and wheelbase of fire engines (see Table 4). Routes will not be adequate for emergency access if they have:

- bridges or other features which make them unusable by fire engines;
- manhole covers not designed for heavy vehicles;
- deteriorated due to bad weather conditions.

Table 4 Typical access requirements for fire engines

Appliance type	Width of road (metres)	Width of gateway (metres)	Turning circle (metres)	Clearance height (metres)	Weight (tonnes)
Pump	3.7	3.1	16.8	3.7	12.5
High Reach	3.7	3.1	29.0	4.0	17–25

15 Wherever practicable, roads likely to be used by emergency vehicles are best kept free of parked vehicles. This should be discussed with the police at the planning stage.

16 Fire engines need to be able to get to within 50 m of any structure, including fuel stores. Turning areas are needed in dead-end access routes longer than 20 m.

17 Aluminium trackway can be useful on soft ground, providing it can take the maximum weight and width of fire engines, especially at changes in direction.

18 On-site emergency vehicle routes need to be clearly marked and kept free from obstruction. Hydrants and other water supplies should be clearly visible and easily accessible. Car parks are best sited away from devices, stalls and other structures. Parking should not be allowed on internal routes.

Spacing between caravans

19 The following guidelines, prepared in consultation with the Home Office, are designed to control fire risks to fairground staff and their families. To be effective, they require good planning, effective liaison with the fire authority and a satisfactory fire safety risk assessment

20 Guidance for residential caravans recommends a spacing of 5 or 6 m between each caravan, depending on type. This may be reduced to not less than 1.5 m for showmen's caravans and other vintage living vans, as long as the fire safety arrangements given in paragraph 22 of this appendix have been made to contain any fire and quickly alert people to it.

21 Articulated tractor units or towing vans used for sleeping should be treated as caravans. They should not remain coupled to other living accommodation. Articulated tractor units or towing vans used as dressing rooms and/or for carrying props and small domestic items, but not used for sleeping, may remain coupled to a caravan. However, there should be at least 5 m between such vehicles unless the fire safety arrangements given in paragraph 22 of this appendix are in place.

22 The arrangements needed before spacing can be reduced are:

- all vehicles and caravans need to be positioned so that they can easily be driven away or hitched up and moved if there is a fire;
- a minimum clear spacing between caravans. Porches and/or awnings do not protrude into the space;
- showmen's living accommodation is adequately separated from public areas, for example, by a barrier/fence or suitable distance (unless the caravans are on display to the public);
- cars are parked away from the living accommodation;
- the organiser has ensured that all operators and attendants have received fire training;
- all electrical equipment is in good working order;
- each caravan has:
  - smoke alarm(s);
  - access to a means of calling the fire brigade;
  - fire-fighting equipment suitable for the hazards present;
  - a notice stating the action to take in the event of fire;
  - for each new site, a prominent notice with the full address of the site;
  - suitable emergency lighting, for example handlamps or torches with spare batteries.

Means of escape in case of fire

23 The organiser should make sure there are arrangements for everyone to be able to escape safely from every structure and from the site itself. They should be based on the findings of the fire risk assessment. Ask the advice of the local fire authority if there is any doubt about what is required.

General principles for means of escape

24 The means of escape in case of fire should allow people, regardless of the location of the fire, to move safely along a recognisable escape route to a place of safety (such as a street or open space) without being overcome by fire, heat or smoke.

25 Escape routes should not contain flammable or potentially toxic materials (including furnishings). They should be kept clear of obstruction, free of slipping/tripping hazards and be available for use at all times.

26 Staff need to be trained to make sure that the public leave promptly and by appropriate routes. Arrangements for helping people with disabilities should also be carefully considered.

Means of escape from structures

27 In some structures (eg funhouses) with features such as sloping or moving floors, the controller may need to make special arrangements to ensure that people can escape if a fire breaks out. These may include mechanisms to stop moving floors and emergency lighting in any dark areas.

Means of escape from the site

28 The exit time for the whole site should be discussed with the fire authority.

29 If outdoor areas are fenced or surrounded by buildings, as in a street fair, the organiser should make sure that there are sufficient means of escape to allow for an orderly evacuation, for example:

- the number and width of escape routes and exits are sufficient for the occupant capacity and suitably located;
- there are arrangements for keeping escape routes and exits clear;
- all exits and gateways are clearly indicated;
- the ground conditions on the escape routes will be suitable, particularly for people with disabilities and families with toddlers and pushchairs.

Requirements for escape routes

30 Passageways:

- should be constructed and laid out to provide safe escape;
- should be at least as wide as the exit served;
- should have a non-slip surface, guard rails and handrails as appropriate;
- the gradient of any ramp should be constant, not exceeding 1:12 nor broken by steps.

31 Exit and directional signs should be:

- clearly indicated;
- in the form of pictograms with directional arrows where appropriate.

32 Lighting requirements are that:

- access and escape routes should have adequate artificial lighting, where necessary;
- emergency lighting should be provided for routes which could be affected by failure of the normal lighting.

33 Emergency lighting may use the same power supply as normal lighting but the lighting units should be provided with an independent power source, which will function immediately and automatically if the normal supply fails. These arrangements should be designed so that loss of supply to particular areas will result in the emergency lighting for that area being activated. New emergency lighting systems should conform to appropriate standards. Automatic emergency lighting should be checked regularly and properly maintained. The emergency lighting on mobile amusement devices should be tested before opening at each new site to make sure that batteries have not become discharged during transit or build-up.

34 All final exit doors and all doors leading to them should be checked each day, before the public are admitted, to make sure that they are unlocked and can be opened easily from the inside. Such doors must never be fastened with padlocks and chains while the structure is in use.

Means for detecting and giving warning in case of fire

35 Make sure that there are suitable means for detecting and giving warning in case of fire. Any warning should be audible throughout the site, giving instant notice to appropriate staff but without causing the public to panic.

36 Where a public address system is not available, other means such as loudhailers should be provided. An alarm bell is not suitable, as members of the public may confuse it with the entertainment. Any instruction to the public to leave immediately should be phrased positively to leave no doubt that it is not part of the entertainment.

Fire-fighting equipment

37 Make sure that the site and structures are provided with appropriate fire-fighting equipment for use by staff for the risks identified. The local fire brigade can give further advice on the most suitable type and location for such equipment.

38 Signs should be displayed to show where extinguishers are located. Staff should be trained to use them and to understand the operating instructions printed on them. This will reduce the likelihood of using the wrong extinguisher.

39 Fire-fighting equipment in outdoor areas may also need to be suitable for tackling fires in vegetation, marquees etc. The organiser may need to consult the fire authority about sources of water for fire-fighting, particularly if the fair is large or there is a high risk of spread of fire.

40 Fire-fighting equipment should be serviced at regular intervals (for example yearly). A test certificate should be obtained for each item.

Good housekeeping

41 The organiser needs an effective fire safety policy which promotes good housekeeping and encourages staff to be aware of the common fire hazards and practical precautions. It is particularly important to check the site carefully at the end of each day. It is a good idea to have another inspection 30 minutes later to make sure that nothing is smouldering.

Special precautions for tented, air-supported and pneumatic structures

42 Tented, air-supported and pneumatic structures can have particular dangers. There are the hazards of ignitability of the material and rapid flame spread together with the possibility of toxic smoke if plastics are present. It is important that the organiser finds out what the structure is made of and seeks further advice if unusual materials are present.

Tented structures

43 The term ‘tented structures’ covers a wide range of structures including:

- large tents housing dark rides at fixed sites;
- boxing booths, travelling exhibitions and similar attractions;
- ghost trains and other mobile rides where part of the structure (usually the back) is made of fabric;
- canopies and awnings in catering areas.

44 It is recommended that all membranes and fabrics used in tented structures be flame retardant. The flame-retardant properties of a fabric may be reduced by weathering or subsequent treatments, eg dyeing. If this occurs, the flame-retardant performance level will need to be restored. Further information on tests for flame retardancy, treatment intervals and methods can be given by the local fire authority.

45 Large tented structures, eg marquees, need to be placed at least 6 m apart to prevent fire spread and allow access by the emergency services. Site them well away from any proposed fireworks displays. Linked tents need to be laid out so that fire engines can get to within 50 m of any part of the structure.

46 Tented structures should have:

- enough emergency exits of a suitable type and size;
- appropriate means of giving warning in case of fire;
- normal and emergency escape lighting and emergency exit signs;
- fire-fighting equipment;
- enough trained attendants to direct the public in an emergency (normally 1 to every 250 people, but 1 to every 75 if the audience is mainly under 16 years of age).

47 Floor coverings need to meet the appropriate British Standard fire tests. Linings and ropes need to be flame retardant. Ropes and cords need to be checked regularly by a competent person and replaced as necessary. All stakes, other types of anchorage and support poles need to be maintained in good order and inspected regularly. Controllers need to make sure that the loss of a supporting rope through fire or other means will not endanger the structure’s stability.

Air-supported structures

48 The fabric of an air-supported structure needs either to be non-combustible or not readily able to support combustion. The foundations and safety features of such structures need to be properly maintained and regularly inspected.

49 The structure needs to meet the requirements of paragraph 46 of this appendix, and in addition have:

- maximum and minimum pressure-limiting devices and audible warnings;
- automatically operated standby fans;
- an alternative power source to operate under pressure loss and/or failure of the primary power source;
- an emergency support system.

Pneumatic structures

50 Pneumatic structures need to be made from suitable flame-retardant materials. They also need reliable air supply systems (with secondary support systems) to maintain clear exit routes in an emergency. The travel distance from any part of the structure to the protection of a secondary support system needs to be no more than 12 m, with a minimum headroom of 2.5 m. Small roofless structures, such as bouncy castles, present less of a problem if they collapse as there is little risk of

people becoming trapped inside.

Gas safety

51 Attractions may be supplied with gas from the mains, or liquefied petroleum gas (LPG) from fixed tanks or transportable cylinders. The main risks from the use of gas are:

- accidental release which can lead to fire, explosion, or asphyxiation;
- build-up of fume or poisonous combustion products, particularly carbon monoxide.

52 Appliances, including items such as catering equipment and gas-powered generators, must only be installed and maintained by CORGI-registered gas fitters. To find a CORGI-registered installer in your area contact CORGI on 0800 915 0485 (www.trustcorgi.com).

53 Every gas installation used in an enclosed area must be properly installed and regularly maintained so that:

- gas is efficiently burned to prevent the production of carbon monoxide;
- there is good general and fixed ventilation for the appliance;
- combustion products are safely dispersed to the open air;
- flues are properly installed and free from leaks and obstructions.

Storing liquefied petroleum gas (LPG)

54 Arrange your LPG storage to prevent two main risks:

- leakage followed by ignition – leaks could arise from damage to the vessel or its associated pipework;
- direct heat on a vessel. The most likely source is a fire close to the vessel, so it is very important to keep other combustible materials well away.

Fixed LPG installations

55 The Liquefied Petroleum Gas Association (LPGA) has over 20 codes of practice on LPG, with several relating to bulk or cylinder storage. These are available from LPGA, Pavilion 16, Headlands Business Park, Salisbury Road, Ringwood, Hampshire BH24 3PB (www.lpga.co.uk).

56 HSE Guidance Chemical Sheet 5 *Small-scale use of LPG in cylinders*[40] gives details on the storage requirements for LPG cylinders when not in use. The recommendations apply equally to 'empty' cylinders as to full ones because they can still contain significant amounts of gas. Remember to store cylinders:

- in a well-ventilated position outdoors on firm, level ground;
- at least 1 m from buildings or boundaries, 2 m from any building openings, drains or gullies and 3 m from other combustible, corrosive or oxidising materials.

57 When in use, site LPG cylinders outside in a well-ventilated position on firm, level ground against the wall of a building or structure (this does not apply to cabinet heaters which are designed to be used indoors and have the cylinder inside the appliance). Any cylinder should be at least 2 m from any openings to cellars or drains and the valve at least 1 m horizontally and 0.3 m vertically below any wall openings, eg opening windows. Protect the cylinders from damage and interference and make sure that you have ready access to the valves in an emergency.

58 Always change cylinders in a well-ventilated area and make sure that there are no naked flames or other sources of ignition in the area while you are doing so.

59 Further guidance on the storage and use of LPG is contained in the LP Gas Association Code of Practice No 24, particularly Part 3 *Use of LPG cylinders in mobile catering vehicles and similar commercial vehicles*.[41]

Preventing other risks

60 Flammable gas should not be used to fill balloons or similar items.

61 It is inadvisable to leave heating appliances which have naked flames unsecured in any structure while the public are present. If an appliance, such as a space heater, is required for boosting temperature in a public space it should be switched off before the public are admitted, wherever possible.

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Glossary

amusement device often shortened to 'device' this includes rides, transportable structures entered by the public (eg haunted houses, arcades, tents and booths) and shooting galleries where hazardous projectiles are fired.

amusement industry the collective term for the fairgrounds and amusement parks industry. It includes the people who design, manufacture, supply, control, operate, attend, maintain and carry out inspection of articles of fairground equipment and other attractions at fairgrounds and amusement parks.

amusement park a fixed site where fairground equipment is provided for the entertainment of the public.

appointed inspection body (AIB): in-service annual inspection the registered inspection body that has overall control of the in-service annual inspection of an amusement device and the responsibility for issuing the Declaration of Operational Compliance (DOC).

appointed inspection body (AIB): pre-use inspections the inspection body that has the overall responsibility for confirming that the pre-use inspections have been completed and for issuing the Declaration of Operational Compliance (DOC).

arcade a transportable structure housing games, stalls or other attractions at a fairground or amusement park. It does not include buildings housing such attractions.

article of fairground equipment any fairground equipment or any article designed for use as a component in any such equipment (definition from Health and Safety at Work etc Act 1974, section 53).

assessment of conformity to design (ACD) the procedures and investigations necessary to confirm that a piece of equipment or a part of it has been manufactured in conformity with a particular reviewed design specification (see also design review).

attendant any person appointed to work under the control and direction of an operator to assist in the operation of an amusement device.

attraction anything provided for the entertainment of the public at a fairground or amusement park, including rides, games and catering stalls.

coin-operated amusement devices devices such as arcade simulators, kiddie cars or kiddie rides. These devices may be inspected by a BACTA-registered ADIPS inspection body.

coin-operated arcade simulator an amusement device designed to enhance the visual effects of a game or video display with a simple non-violent motion. It is mounted on a stationary base incorporating measures designed to 'fail safe' in the event of a structural, electro/hydraulic or pneumatic failure. The seat height should not exceed 1.5 m from the ground. The device is operated by coins or tokens etc and is designed for the unattended use of no more than two people.

> A non-violent movement is one that is not likely to cause a user to be dislodged or fall over resulting in an injury, eg cause people to strike their head etc on the sides of the seats. A 'fail safe' measure is one that will not cause a risk to the safety of a passenger or the public, or others. If any doubts exist, a full inspection procedure, including design review and conformity should be carried out by an ADIPS registered inspection body.

coin-operated kiddie car a battery-powered vehicle with a maximum speed consistent with that laid down in EN 13814[42] and operated by coins or tokens etc. Designed for the unattended use of children between the ages of 3 and 10 years within the strict confines of a specially designed track.

coin-operated kiddie ride a slow-moving device fitted on a stationary base operated by coins or tokens etc, primarily designed for the unattended use of one or two people between the ages of 3 and 10 years.

> Although a ride is designed primarily for the use of children between 3 and 10 years, this does not mean that a parent or guardian cannot accompany the child if the ride is suitable. In certain circumstances the ride may seat more than two people, in which case special conditions should be applied. Rides with more than two seats should be designed (ie slow or gentle movement or other safety measures), to ensure a child will not sustain injury if boarding or alighting when the ride is enabled. The ride should have a sign advising that the passengers should be seated before a coin is inserted and other measures considered such as 'soft start'.

commissioning tests tests designed to compare the performance of a new or modified piece of equipment against its specification.

controller the person or organisation having the overall control of an amusement device (including maintenance and safe use). This may be either an individual or corporate body owning an amusement device or the concessionaire or lessee who has been granted control of the device, by the owner, for a specified time.

daily check an operational check carried out before an attraction is made available to the public, to determine whether or not an amusement device is in such a condition that it may continue to be operated safely. The controller or a person nominated by the controller should do it. The check should identify any defects and indicate what replacement, repair or adjustment is needed before the attraction can be used. For an amusement device, it should also include a trial run with a functional check of any safety-related systems to make sure that they are properly adjusted and work in accordance with the operations manual.

Declaration of Operational Compliance (DOC) the safety certificate that is that is issued by a registered inspection body (RIB) after the satisfactory completion of all the relevant in-service annual inspections on an amusement device. It is used to certify that the device is safe to operate for a period of no longer than 12 months, or less if specified by the inspection body.

design review the procedures and investigations necessary to confirm that the safety-critical aspects of the design of a passenger-carrying amusement device are sound in concept and that the calculations are satisfactory.

design specification documents, drawings, software etc which together make up the descriptions of function, operation, construction, workmanship and materials.

design risk assessment the process of assessing the hazards that the design of a piece of fairground equipment may pose, the likelihood of those hazards posing a risk and the control measures that are necessary to adequately control those risks. Designers should assess the significant risks that arise from its subsequent assembly/dismantling, transport, inspection, maintenance and operation.

device abbreviation for the term ‘amusement device’.

dutyholder any person who has duties imposed on them by any relevant statutory legislation.

fair an event at which fairground equipment is used for entertaining the public.

fairground any part of premises which is for the time being used wholly or mainly for the operation of any fairground equipment other than a coin-operated ride or non-powered children’s playground equipment. It includes both fixed amusement park and temporary sites.

fairground equipment any fairground ride, or any similar plant which is designed to be in motion for entertainment purposes with members of the public on or inside it or any plant which is designed to be used by members of the public for entertainment purposes either as a slide or for bouncing upon, and includes swings, dodgems and other plant which is designed to be in motion wholly or partly under the control of, or to be put in motion by a member of the public. This definition was inserted in the Health and Safety at Work etc Act 1974, section 53, by an amendment enacted by the Consumer Protection Act 1987. The definition is held to include coin-operated children’s rides, but not non-powered children’s playground equipment.

functional test a test or combination of tests designed to investigate whether an amusement device continues to carry out its safety-critical functions. The tests may need to include measures of both function and performance using conditions and loading appropriate to those likely to occur in use.

hazardous projectiles mechanically fired projectiles, which could cause personal injury, including live ammunition; other metal projectiles designed to be fired by compressed air, eg pellets, darts and balls; crossbow bolts; and any targets which are projectiles, eg clays. It does not include hand-thrown projectiles.

initial test tests required to confirm that a newly constructed, imported or modified amusement device operates in accordance with a specification which has been the subject of a successful independent design review. Commissioning tests do not substitute for an initial test, but an inspection body may take account of relevant data from such tests as evidence of performance of a device under particular conditions as part of the overall initial test.

in-service annual inspection the procedures, tests and investigations necessary for an appointed inspection body to decide whether an amusement device may continue to be operated safely, or that it requires defects to be remedied either immediately or in a specified time before the device may be operated over a specified period of time.

inspection examination of a product design, product, service, process or plant, and determination of their conformity with specific requirements or, on the basis of professional judgement, general requirements.

log book a section of the operations manual which allows a record to be kept by past and present controllers to provide details of any in-service annual inspections, modifications and repairs that may have been carried out. It would be helpful to retain in this section written records of any examination and inspection work done on the device, including the daily checks.

maturity design evidence from past experience that a design or a component of a design has a history of safe functioning. Such evidence needs to be scrutinised carefully to make sure that it is wholly relevant to any importance that is to be placed on it.

operational limits the limits recorded in the operations manual within which an amusement device should be used.

operations manual full instructions for safe use compiled by the designer, manufacturer, importer or supplier (updated by the user) containing documentary proof of all inspection reports and records of any modifications as well as other records previously kept in the log book.

operator the person appointed by the controller to be in charge of the immediate operation of an attraction at any time when it is intended to be available for public use.

organiser the person who has overall control of a fairground or amusement park. This may be an individual or a corporate body. The organiser may, for example, own the site; be a concessionaire or lessee who has been granted control of the site for a specific period; or have been appointed or elected to co-ordinate the activities of a number of individual employers or self-employed people working at the site.

packing material used between the stationary framework and the ground/ foundations to make adjustments for variations in levels.

passenger-containment system a system comprising one or more components, eg seating, footwells, handrails and passenger restraints designed to prevent passengers moving outside a predefined area on a ride either as a result of the ride forces or the behaviour of the passenger.

passenger restraint a particular part of the passenger-containment system moved into position and used to hold a passenger in one place or prevent movement of particular parts of their body, eg lap bars and seat belts.

repair restoration of safety-critical components or safety-critical assemblies to an acceptable condition by mending of worn, damaged or decayed parts, which does not result in a deviation from the design specification.

registered inspection body (RIB) an inspection body registered with a scheme that has been agreed by the member associations and the Health and Safety Executive (at the time of publication the only such schemes are the Amusement Devices Inspection Procedures Scheme (ADIPS) for all amusement devices, and the PIPA scheme for inflatables).

ride a fairground ride. This has the same meaning as the legal definition of 'fairground equipment', found in section 53 of the HSW Act.

safety the freedom from unacceptable risks of personal harm (BS 4778 Part 3: Section 3.1 1991[43]).

safety-critical component any type of component on an amusement device on which the safety of the passengers (or others who may be affected) is dependent.

safety-critical modification any alteration to the hardware and/or software of a piece of equipment including the introduction of a safety-critical component which results in a deviation from the original design specification.

safety envelope the minimum space around the moving part of a ride necessary to make sure that passengers or other people such as spectators cannot be injured through contact with either static or moving parts. Calculations of the safety envelope should take account of the maximum foreseeable size of people who could be at risk and dynamic as well as static reaches.

stall any other attraction, for example, hoopla, catering trailer etc.

trial run proving run of an amusement device during which no passengers are carried.

Further information

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Showmen's Guild of Great Britain, Guild House, 41 Clarence Street, Staines, Middlesex TW18 4SY Tel: 01784 461805 Website: www.showmensguild.co.uk

Safety of Amusement Devices: Design

ADIPS

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This guidance is issued by ADSC on behalf of the industry associations listed in the Foreword. It is endorsed by the Health and Safety Executive. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

Safety of Amusement Devices: Design

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Foreword

This guidance sets out what the Joint Advisory Committee on Fairgrounds and Amusement Parks considers are appropriate measures for those involved in design, and others in the industry, to work safely and comply with the law. The following industry associations, in alphabetical order, together with the Health and Safety Executive (HSE) are represented on the Committee:

- The **Amusement Catering Equipment Society** (ACES) 1 Delamere Road, Turf Hill, ROCHDALE, 01-16 4XD. Tel: 01706 869841

- The **Association of Independent Showmen** (AIS) 53 Lowick Gardens, Westwood, Peterborough, PE3 7HD

- The **Association of Leisure Equipment Suppliers of the United Kingdom** (ALES) 1st Floor, 74 Kilbury Drive, WORCESTER, WR5 2NG. Tel. 01905 360169 Fax. 01905 360172

- The **British Amusement Catering Trade Association (BACTA)** Alders House, Aldergate LONDON, EC1A 4JA Tel: 020 7726 9826 Fax: 020 7726 9822

- The **British Association of Leisure Parks, Piers and Attractions** (BALPPA) 57 - 61 Newington Causeway, LONDON, SE1 6613. Tel: 0207 7403 4455 Fax: 0207 7403 4022 www.balppa.org

- **Health & Safety Executive** (HSE) 375 West George Street, GLASGOW, G2 41-W. Tel: 0141 275 3000 Fax: 0141 275 3015 www.hse.gov.uk

- The **National Association for Leisure Industry Certification** (NAFLIC) PO Box 752, SUNDERLAND, SR3 1XX. Tel: 0191 5239498 Fax: 0191 5239498 www.naflic.org.uk

- The **Showmen's Guild of Great Britain** (SGGB) 41 Clarence Street, STAINES, TW18 4SY. Tel: 01784 461805 Fax: 01784 461732

- The **Society of Independent Roundabout Proprietors** (SIRPS) 66 Carolgate, RETFORD, DN22 6EF. Tel: 01777 702872

This publication has been written taking into account the contents of the European Standard EN 13814: 2004, modified where necessary to conform to British legislation and the amusement industry's agreed and accepted practices (see Appendix 3).

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Chapter 1

Design risk assessment

General

1. Design Risk Assessment (DRA) is the process of assessing the hazards that the design of a piece of fairground equipment[1] may pose, the likelihood of those hazards causing a risk and the control measures that are necessary to adequately control those risks[2]. Designers should assess the significant risks that arise from its subsequent assembly/disassembly, transport, inspection, maintenance and operation. This Chapter has been prepared as guidance for designers and others, such as persons importing or supplying amusement devices, on what information a DRA should contain.

2. Effective safety management emphasizes the need to assess and control risk. In Great Britain this principle is laid out in the *Management of Health and Safety at Work Regulations 1999* and in the accompanying Approved Code of Practice and Guidance.

3. The Regulations require employers and self-employed persons to carry out assessments of risks to the health and safety of themselves (in the case of self-employed), their employees, and others.

4. In addition to this general duty to assess risk, there is also an explicit duty placed upon those who design fairground rides to ensure that they are safe[3]. Safe in this context means safe for the operators, attendants and those who inspect and maintain an amusement device as well as the members of the public who ride them. Bearing in mind that risks are typically heavily dependent on decisions made at the design stage, the process of design risk assessment is crucial to confirming the safety integrity of the ride.

5. The Health and Safety Executive and fairground industry associations in Great Britain have produced guidance "Fairgrounds and Amusement Parks – Guidance on Safe Practice (HSG175)". This introduced the idea of "Design Review" for amusement devices. This is the process where an inspection body registered with ADIPS, and independent of the original design, reviews the safety critical aspects to ensure the integrity of the design

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[1] An "article of fairground equipment' means any fairground equipment or any article designed for use as a component in any such equipment.

[2] A "Hazard" means anything that can cause harm (e.g. chemicals, electricity, working at height, machinery, etc). The "Risk" is the chance, high or low, that somebody will be harmed by the hazard.

[3] The legal duty to ensure that the design of a fairground ride is safe is contained within The Health and Safety at Work etc Act 1974 (as amended by the Consumer Protection Act 1987), and associated Regulations which apply in Great Britain. In particular in Section 6(1A) & 2 of the Act, which states:

(1A) It shall be the duty of any person who designs, manufactures, imports or supplies any article of fairground equipment' —

a. to ensure, so far as is reasonably practicable, that the article is so designed and constructed that it will be safe and without risks to health at all times when it is being used for or in connection with the entertainment of members of the public;
b. to carry out or arrange for the carrying out of such testing and examination as may be necessary for the performance of the duty imposed on him by the preceding paragraph;
c. ……….
d. ……….

(2) It shall be the duty of any person who undertakes the design or manufacture of an article for use at work or of any article of fairground equipment to carry out or arrange for the carrying out of any necessary research with a view to the discovery and, so far as is reasonably practicable, the elimination or minimisation of any risks to health or safety to which the design or article may give rise."

assumptions (see Chapter 13).

6. If a designer does not directly arrange for "Design Review" to be done, the industry agreed guidance HSG 175 makes it clear that it will be necessary for him to provide adequate data to the manufacturer, importer or supplier as appropriate so that they can have it done. The designer's risk assessment is a crucial element of this data.

7. Fairground equipment is largely excluded from European Directives and is specifically excluded from the Machinery Directive. There are however a number of helpful European and International Standards dealing with issues of hazard and risk which have been used as source material in the following paragraphs of this Chapter. The principle of making use of such sources is to maintain some consistency with other types of machinery and structures, where this is justifiable.

8. The advice in this publication is based in part on the (British and) European Standard EN 1050[4] - Safety of machinery. Principles for risk assessment. This is a Standard which many European designers of fairground equipment consider to be appropriate when designing amusement devices. Risk assessment principles for machinery are also developed in ISO 141214[5]. Much of the content of these Standards can also be satisfactorily applied to other equipment such as structures, although it is recognized that some variations are necessary in the application of machinery standards to amusement devices.

9. For international terminology relating to hazard, risk and related matters, ISO/IEC Guide 735[6] provides definitions.

More than one Designer - Responsibilities

10. It is normal for an amusement device design to combine a number of different technical disciplines (e.g. structural, mechanical, hydraulics, electrical, lighting, and control systems) which may involve input from different designers. Even within one discipline there may be good reason for more than one designer to be used (e.g. some work may be subcontracted). There may even be more than one designer associated with each single component - for instance, one designer may prepare a passenger containment layout, another may do the structural calculations, and yet another may carry out the ergonomic assessment of it.

11. Where multiple designers are used effective assessment of all relevant risks will need effective management to ensure completeness.

12. Responsibilities are determined, at least in part, by allocation down the contractual chain or chain of command. For instance, where subcontracts (which are often verbal) are placed to carry out parts of the design or modifications to an amusement device, each person in the chain needs to consider what risks relate to his specific undertaking and what needs to be done to control them. The extent of the risk assessment work that each of these various subcontractors needs to undertake depends on the extent of their contracts or instructions.

13. This duty is created and its limits defined by The Health & Safety at Work etc Act 1974 S6, subsection 6(7), which says that:

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[4] EN 1050 Safety of machinery. Principles for risk assessment
[5] ISO 14121 Safety of machinery. Principles of risk assessment
[6] ISO / IEC Guide 73 Risk management. Vocabulary. Guidelines for use in standards.

(a) "Any duty imposed on any person by any of the preceding provisions of this section shall extend only ... to matters within his control."

14. For example, in the case of a single component (in the absence of specific instructions to the contrary) it would not be expected that the designer would have to assess risks that only arise when the component is combined with other components which were designed elsewhere. But as the individual components come together there is a responsibility on the person higher up the contractual chain or chain of command who brings these items together to ensure that the associated risks are properly assessed and controlled. He, since he may not personally have the required expertise, is at liberty to allocate or subcontract the risk assessment of the combined assemblage of components, but he may not avoid the responsibility for ensuring that it is done.

15. The intricacies of the relationships and the allocation of responsibilities may be complex where amusement devices are concerned. Subsection 6(8) of the HSW Act recognizes this complexity and the limits of responsibility :-

(a) "*(8) Where a person designs ... an article of fairground equipment and does so for or to another on the basis of a written undertaking by that other to take specified steps sufficient to ensure, so far as is reasonably practicable, that the article will be safe and without risks to health at all such times as are mentioned in paragraph (a) of subsection (1) or, as the case may be, in paragraph (a) of subsection (1) or (1A) above, the undertaking shall have the effect of relieving the first-mentioned person from the duty imposed by virtue of that paragraph to such extent as is reasonable having regard to the terms of the undertaking."*

16. This means that a person higher up the contractual chain or chain of command may take responsibility (in writing) for the safety of work that he has undertaken to do on behalf of another which would otherwise have fallen on that person. But note the words "to such extent as is reasonable having regard to the terms of the undertaking." The intent is not to avoid safety responsibilities but to clarify the process when more than one person is involved. Furthermore, there will remain a duty on the first person to pass adequate information about his work up the chain.

17. HSG 175, Appendix 2 outlines that, in managing the design process it may be relevant to "identify the people, departments and organisations responsible for carrying out and reviewing safety-related activities". Bearing in mind subsection 6(8) of the HSW Act quoted above, it may be necessary for this, or some of it, to be in writing - it would certainly be good practice.

18. It may be appropriate for a person commissioning design work, or a person who imports or supplies an amusement device, to appoint a person to co-ordinate the work (which may be himself if he has appropriate competence) and to inform the relevant parties in writing. That person should check the way in which the elements of the design combine and have the final responsibility for making sure that every safety-related aspect has been covered

Amusement Devices - Risk Assessment in Great Britain

19. The information in this Chapter draws on knowledge and experience of design, operation, incidents, accidents and resultant harm associated with fairground and amusement park machinery and structures. Some known hazards are identified for consideration in a standardised assessment process, but any DRA may need to take into account additional hazards not mentioned here.

20. As noted at the beginning of this Chapter, the term "hazard" means anything that has the potential to cause harm (e.g. , electricity, working at height, machinery, chemicals, etc). Risk is the probability, high or low, that somebody will be harmed by the hazard.

21. The Court of Appeal, in R v. Board of Trustees of the Science Museum7 held that the term "risk" in s.3, HSWA, means the possibility of danger rather than actual danger. In the case in point a failure to adequately chemically disinfect a water cooling tower had potentially exposed the public to legionella bacteria and a risk of contracting legionnaire's disease. The question of whether or not there had been actual harm imposed (e.g. exposure to legionella bacteria) was found to be irrelevant. Designers should bear this in mind when considering the risks that their design may pose to others in the DRA.

22. When there is significant hazard potential for serious injury, the designer will be expected to demonstrate suitably low risk. It is at the design stage that most can be done to ensure that persons are adequately protected.

23. A designer is expected to consider as far as reasonably practicable hazards that may occur as a result of his design. Decisions on whether or not additional measures are required to mitigate the hazard should be based on an assessment of the severity of the possible harm associated with the hazard and the probability of its occurrence (the risk).

24. The term "reasonable practicability" may raise questions amongst designers who are uncertain as to how far they need to go to comply with their duty. A designer must balance the level of risk against the measures needed to avert the risk, whether in money, time or trouble. A key British criminal case which provides a steer on this matter is Edwards V National Coal Board8 . In this case, the Court of Appeal considered whether or not it was reasonably practicable to make the roof and sides of a road in a mine secure. They concluded that;

- *"... in every case, it is the risk that has to be weighed against the measures necessary to eliminate the risk. The greater the risk, no doubt, the less will be the weight to be given to the factor of cost."*

and

- *"'Reasonably practicable' is a narrower term than 'physically possible' and seems to me to imply that a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them - the risk being insignificant in relation to the sacrifice - the defendants discharge the onus on them."*

The Risk Assessment process

25. The technique of risk assessment formalizes the intuitive process by which designers and safety engineers use their experience to identify hazards, estimate risk and select appropriate control measures.

[7] R v Trustees of the Science Museum [1993] 3 All ER 853,
[8] Edwards V National Coal Board [1949] 1 KB 704; [1949] 1 All ER 743

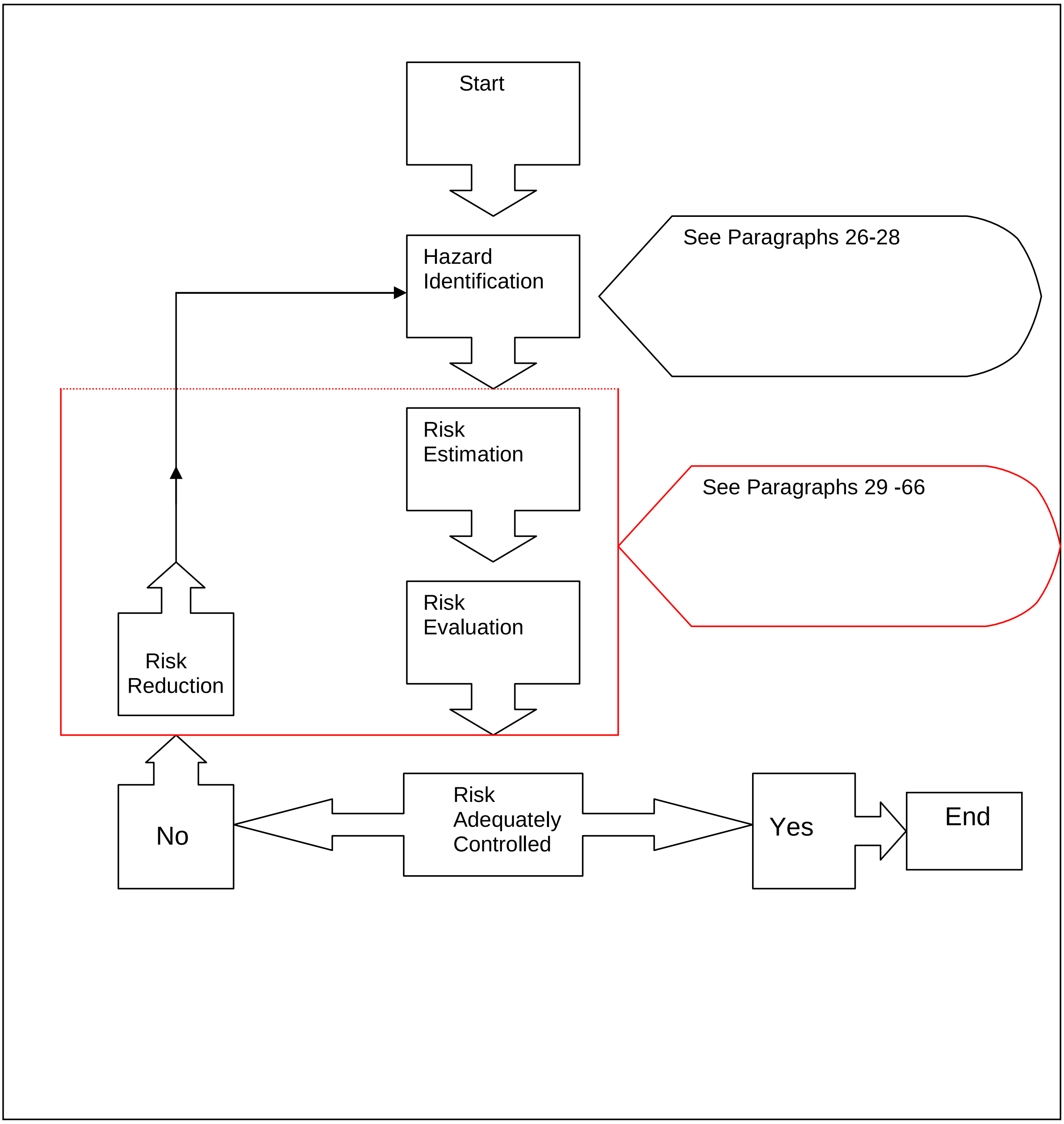

Figure 1.1 the design risk assessment process

Hazard identification

26. Because of the nature of fairground rides some of the hazards encountered in amusement devices are different from those associated with machinery in general, such as those shown in Table A.1 of EN 1050: 1996. For example the fact that the public interact with amusement devices changes the normal design procedure of removing people from machinery proximity. A list of some of the more common hazards encountered in

fairground and amusement park machinery and structures is shown in Table A.1 (Appendix 1).

27. A designer should consider the hazards posed by the limits of the amusement device e.g.:

(a) the different aspects of the amusement device's life (e.g. build-up / pull down, maintenance, inspection, test and operation for use by the public);

(b) The effectiveness of measures to ensure that the motion envelope does not pose a hazard to passengers or others.

(c) foreseeable wear and tear and the effects that may have on integrity;

(d) the intended use (both the correct use and operation of the machinery as well as the consequences of reasonably foreseeable misuse or malfunction);

(e) the full range of reasonably foreseeable uses (and abuses) of the amusement device by passengers identified, as appropriate, by sex, age limit, height limit, and limiting mental and physical abilities. (Human reliability analysis techniques may be usefully applied to fully understand the range of uses and abuses possible);

(f) reasonably foreseeable exposure of other members of the public (e.g. passers by) to the hazards of the amusement device.

28. The following chapters provide advice on many of the hazards identified in Table A.1, and where they are mentioned the associated Chapters and paragraphs are identified in the right hand column of the Table. However, amusement park devices and structures are diverse and the extensive variants precludes specific advice on them all within this guidance. Hazards which are identified and which are not listed in Table A.1 should also be assessed in accordance with the procedures described in this Chapter. Particular care should be taken in identifying non-standard circumstances and assessing whether control measures are needed.

Risk Estimation

29. Risk estimation should be carried out for every potential consequence or accident that is reasonably foreseeable from each identified hazard by assessing the two elements of risk

(a) The severity of the harm

(b) The probability of the occurrence of that harm

30. The severity of harm is normally measured by the likely severity of injuries (i.e. slight, serious or fatal) in combination with the extent of harm (i.e. the number of persons that would be harmed if the hazardous event were to happen). The probability of occurrence of the harm is a function of the frequency and duration of the exposure of persons to the hazard, the probability of occurrence of the hazardous event, and the technical and human possibilities to avoid or limit the harm.

31. Information for risk estimation and any qualitative and quantitative analysis should include the following, as appropriate:

(a) limits of the amusement device (see paragraph 27);

(b) design drawings or other means of establishing the nature of the amusement device;

(c) information concerning sources of energy;

(d) any accident and incident history (where available).

32. Comparisons between similar hazardous situations associated with different types of amusement device are often possible, provided that sufficient information about hazards and accident circumstances in those situations is available. The absence of an accident history, a small number of accidents or low severity of accidents for a particular model of amusement device should not be taken as an automatic presumption of a low risk.

33. For quantitative analysis, data from data bases, handbooks, laboratories and manufacturers' specifications may be used provided that there is confidence in the suitability of the data. Uncertainty associated with this data should be identified in the completed documentation. Data based on the consensus of expert opinion derived from experience may be used to supplement qualitative data.

34. Several methods are available for the systematic analysis of these elements in relation to complex combinations of events (this only applies to a small number of hazardous events associated with amusement devices). Examples are given in Annex B of EN 1050:1996.

35. When estimating the probability of occurrence of harm the frequency and duration of exposure to risk can be influenced by :

(a) need for access to the danger zone (e.g. for normal operation, maintenance or repair);

(b) time spent in the danger zone

(c) the proportion of time for which the danger exists

(d) the number of people requiring access

(e) the frequency of access

36. However to avoid high risk situations becoming hidden by rigid application of the “time at risk” argument it is generally accepted that risks for such activities should be presented both with and without the application of time at risk factors, to enable the full implications of the arguments to be properly considered. An example of this is where a lift door might only affect someone passing through it for a very brief moment; however due to the high hazard nature and the number of affected persons, the time at risk has little relevance.

37. The accuracy of estimation of the probability of occurrence of a hazardous event, whether of a technical nature or resulting from human behaviour, may be improved in some circumstances if:

(a) there is applicable reliability and other statistical data available;

(b) there is relevant accident history;

(c) risk comparison with similar situations is possible).

38. If the probability distribution of time-to-failure is non-linear, there may be a need to carry out more than one estimate of the probability of occurrence of a hazardous event in order to determine the worst relevant case.

39. Two failure modes in particular, i.e. early mortality failures (often associated with initial defects), and aging or wear failures, may require more than one estimate of the probability of occurrence of a hazardous event.

40. The third main failure mode, random failure, should be treated in accordance with the principles of probability theory. (e.g. an extreme wind load is equally likely to occur at any point during the lifetime of the device, as are many electrical / electronic component failures, particularly when combined in circuits involving many components)

41. The possibility of avoiding or limiting harm may be influenced by matters such as:

(a) staff training;

(b) public awareness of risk enhanced by general information, by direct observation, or through warning signs and indicating devices;

(c) the human possibility of avoidance or limiting harm (e.g. reflex, agility, possibility of escape) - this may be possible, possible under certain conditions, or impossible;

(d) by practical experience and knowledge of the machinery, or of similar machinery (although the lack of such experience should be the default assumption).

42. Risk estimation should take into account all persons exposed to the hazards. This includes members of the public (including passengers on rides), operators, attendants, inspection / maintenance staff, installers of fixed equipment, those involved in build-up / pull down of travelling devices, and any other persons for whom it is reasonably foreseeable that they could be affected by the amusement device.

43. The estimation of the exposure to the hazard under consideration requires analysis of, and should account for, all modes of operation of the amusement device and methods of working. In particular this affects the need for access during build-up / pull down, training, passenger loading / unloading, cleaning, fault finding and maintenance. Risk estimation should account for situations when it may be necessary to suspend or override safety functions (e.g. during maintenance).

44. The relationship between an exposure to a hazard and its effects should be taken into account. The effects of accumulated exposure and synergistic effects shall also be considered. Risk estimation when considering these effects shall, as far as practicable, be based on appropriate recognized data. Note that accident data may be available to indicate the probability and severity of injury associated with the use of a particular type of amusement device with a particular type of safety measure.

45. Human factors can affect risk and shall be taken into account in the risk estimation. This includes, for example:

(a) interaction of persons with the amusement device;

(b) interaction between persons;

(c) psychological aspects;

(d) ergonomic effects;

(e) capability of persons to be aware of risks in a given situation (e.g. in relation to ride operators or maintenance staff) depending on their training, experience and ability.

46. The estimation of the ability of exposed staff shall take into account the following aspects:

(a) application of ergonomic principles in the design of the device;

(b) natural or developed ability to execute the required tasks;

(c) awareness of risks;

(d) level of confidence in carrying out the required tasks without intentional or unintentional deviation;

(e) temptations to deviate from prescribed and necessary safe working practices.

47. Training, experience and ability might reduce the risk but none of these factors should be used as a substitute for risk reduction by design or safeguarding where such safety measures can be reasonably practicably implemented. Due to the exposure of large numbers of members of the public, inappropriate reliance should not be placed on ride operators / attendants having to develop an unreasonable degree of skill or acquired knowledge to ensure public safety.

48. Risk estimation should take into account the reliability of components and systems.

49. When more than one safety-related device or system is to be provided to give a degree of redundancy, consideration needs to be given to dependent or common mode failures .

50. When safety measures include:

(a) work organisation,

(b) correct behaviour,

(c) diligence,

(d) application of personal protective equipment,

(e) skill or training,

The relatively low reliability of such measures, as compared to proven technical safety measures, should be taken into account in the risk estimation. Where it is reasonably practicable to employ technical and or physical safety measures this should be done in preference to relying upon those measures listed above.

51. Risk estimation may need to take into account the likelihood that safety measures might be defeated or circumvented. for example where:

(a) the safety measure slows down throughput, or interferes with any other activities or preferences being carried out;

(b) the safety measure is difficult to use;

(c) the safety measure is not recognized as such, or is not accepted as suitable for its function.

Risk Evaluation & Reduction

52. Risk evaluation should be carried out to determine if risk reduction is required or whether safety has been achieved.

53. If risk reduction is required, then appropriate safety measures should be selected and applied, and the procedure repeated (see figure 1).

54. The following hierarchical principles of prevention should be considered when evaluating risk:[9]

(a) Avoiding risks

[9] *Management of Health and Safety at Work Regulations 1999, Schedule 1 General Principles of Prevention as set out in Article 6(2) of Council Directive 89/391/EEC)34*

(b) Evaluating risks which cannot be avoided

(c) Combating risks at source.

(d) Adapting to technical progress

(e) Replacing the dangerous by the non-dangerous or the less dangerous

(f) developing a coherent overall prevention policy which covers technology, organisation of work, working conditions, social relationships and the influence of factors relating to the working environment

(g) giving collective protective measures priority over individual protective measures; and

(h) giving appropriate instructions to employees

55. During this process, it is important for designers to check whether additional hazards are created when new safety measures are applied. If additional hazards do occur, they should be added to the list of identified hazards and the risk reassessed.

(a) Where control measures include safeguarding (provision of guards, barriers, restraints, etc.) then the assessment should consider if :-

(b) the safeguarding selected provides a safe situation for the intended use;

(c) the type of safeguarding selected is appropriate for the application in terms of:

i. probability of defeat or circumvention;

ii. severity of harm;

iii. hindrance to the execution of the required task (in the case of hazards affecting staff);

56. If after risk reduction, some residual risk remains, further mitigation measures required should be clearly communicated to the ride controller.

Documentation of Design Risk Assessment

57. At the end of the design process there is a need to record some information about the design risk assessment, not least so that others having a legitimate interest may see what has been done and what the residual risks might involve.

58. The risk assessment document should include when relevant:

- details of the amusement device design for which the assessment has been made (e.g. unique reference numbers, specifications, limits, intended use);
- any relevant assumptions which have been made (e.g. loads, strengths, safety factors) which differ from or are additional to recommendations in this publication;
- the hazards identified.
- The control measures and any further action required
- Residual risks.

59. In Great Britain, this information - the documented design risk assessment - has to go forward to the process known as Design Review carried out by an ADIPS Registered Inspection Body. More details of what this should include, and information to be provided to others, are given in Chapter 13.

Relevant Standards & Other Publications

ISO/IEC Guide 73: 2002 ISO 14121	Risk management - Vocabulary - Guidelines for use in standards Safety of machinery. Principles of risk assessment
EN 1050	Safety of machinery. Principles for risk assessment
HSC13REV1	Health and Safety Regulation: A short guide. HSE Books; 2003.
HSG 175	Fairgrounds and Amusement Parks - Guidance on Safe Practice HSE Books; 1997.
R2P2	Reducing Risks, Protecting People (HMSO; first published 2001)
	Review of Fairground Safety, Report to the Health and Safety Commission; August 2001

Chapter 2
Principles of Dynamic Analysis

General

1. Many amusement devices may be considered dynamic devices. They are specifically designed to cause the passenger to experience changes in position, velocity and acceleration.

2. The loads thus imposed are examples of dynamic loads. The dynamic response of a structural system depends on the load, natural frequency and damping and the participating mass of the system.

3. Variations in acceleration, cause variations in forces and component stresses which can lead to fatigue. Indeed experience shows that most structural failures and damage occurring in dynamic amusement devices result from fatigue. Experience also shows that there are common failings in the methods and accuracy of dynamic analysis of amusement devices - hence the need for this part of the Guidance.

4. Special methods are required for the fatigue analysis of particular design features and these influence the requirements of dynamic analysis. The calculation of fatigue life requires a knowledge of the stress history of the design detail; i.e. the variation of the stress must be calculated. This, of course, means that the dynamic forces and moments should, in general, also be evaluated as functions of time.

5. If the forces, moments and stresses are not calculated as functions of time then worst case stress magnitudes and ranges will need to be justified and demonstrated to be suitably pessimistic. The designer will be aware that this can lead to over-elaborate structures and mechanisms.

Vector Analysis

6. Since velocities, accelerations and forces are vector quantities, i.e. having both magnitude and direction, the principles of vector analysis should be applied. Many amusement devices involve motions in three space dimensions and the use of three dimensional Cartesian (or other) vector notation is often the only realistic means of ride analysis.

Rigid Body Dynamics

7. The basis of dynamic analysis is Newton's Laws of Motion. In their simplest form these laws apply to particles having finite mass but infinitesimal size. But amusement devices contain components of finite size and the extensions of Newton's Laws into Rigid Body Dynamics must be used. That is to say that, for many ride components, moments and products of inertia are important.

8. While it is sometimes true that reasonable results may be obtained by approximating ride components by a reduced set of point masses, it is also true that, in other instances, large errors may result. Thus, if the moments and products of inertia of a ride component are not used (in determining its rate of change of angular momentum) it is important that an error estimation be carried out to justify the approximation.

Devices having One or More Degrees of Freedom

9. In amusement devices, as with other dynamic systems, the input controls impart known time or position dependent variations to the dependent variables. So, for instance, one might specify the time history of a rotational speed in a simple rotating device, or the release position and velocity of a roller coaster train.

10. In the simplest devices (e.g. Twist), once the input parameters are specified, the accelerations and forces may be calculated using basic differential calculus. In more complicated devices there may be additional degrees of freedom (e.g. Matterhorn car swing) which require the solution of complex differential equations of motion before all of the required force and moment vectors can be calculated.

11. In many of these more complicated devices the additional degrees of freedom have been deliberately introduced and are an important feature of the ride. As such the variations in the dependent variables are not small in magnitude and the differential equations are non-linear containing time and position dependent coefficients. Differential equations of this type exhibit regions of instability. Indeed the feature of many rides of this type is that they operate in regions of instability or near-instability in order to achieve the desired effect (e.g. the spinning of Octopus cars or the large swing angles of Matterhorn cars).

12. Realistic modelling of most devices of this type is unlikely to be achievable without the use of rigid body dynamics and appropriate computer software. The analytical assessment of component fatigue lives is, of course, dependent on the dynamic model and its solution being of sufficient accuracy.

Devices having Zero Degrees of Freedom – General

13. The analysis of simpler amusement devices not requiring the integration of differential equations also has some common pitfalls. The design engineer must remember that gyroscopic moments are dependent on the angle between the two interacting axes. So, for instance, on a Trabant the angle between the rotor spin axis and the vertical is relevant. Another occasional error is to reverse the direction of a gyroscopic moment vector, which will affect the stress analysis of some of the dependent components.

14. An even simpler class of amusement device has zero degrees of freedom (i.e. no differential equations to solve) and all motions remaining parallel to a plane (i.e. two dimensional motion). A typical example would be a Twist. Although simpler methods can often be employed for rides in this class they are not without their pitfalls. Two typical errors result from making assumptions about the position of a rigid body's instantaneous centre of rotation from the position diagram; and ignoring or miscalculating Coriolis accelerations. The first of these snags can be avoided by drawing the velocity and acceleration diagrams. The second is avoided only by careful procedure as with the calculation of other components of acceleration.

Unwanted Vibrations

15. The large swinging motion of, for example, a Matterhorn car is a designed-in vibration. However, there is often a need to design light, economical structures which are, as explained above, subject to varying positions, velocities, accelerations and forces. These variables may excite unwanted, small amplitude, structural vibrations.

16. Vibration is particularly likely to be a problem at or near resonance when a periodic excitation occurs at a frequency close to a structural natural frequency. In order to avoid

problems it is necessary to form an approximation, to be refined if necessary, of the excitation frequencies and any natural frequencies likely to be significantly excited. So, for instance, in track-following rides excitation may arise from passing over track supports or rail joints and in rotating rides the basic rotational frequency may be the source of excitation.

17. These are, perhaps, obvious sources of excitation but it is important to remember that, as Fourier Series expansion will show, the dynamic excitations in many rotating amusement rides can contain higher harmonics of rotation speed. The designer must therefore be aware that sub-harmonic resonances can occur and structures may need stiffening to make the lowest natural frequency much higher than the basic rotational frequency.

18. An often mentioned source of vibration, and hence additional dynamic forces, is the motion of wheels over rail or tram joints. In this connection it is worth noting that, while slight gaps between adjacent rails are not of great significance, any misalignment causing an effective "step" up or down which the wheel must climb may cause significant vibratory dynamic loading. At very slow speeds this loading becomes small, but otherwise and when the tyre provides the only flexibility the maximum additional load is given by the step height multiplied by the tyre stiffness of a complete axle (i.e. normally four tyres). Clearly calculation of this additional load may be used in assessing component strength, but it also may be used as a guide in the selection of tyres or the setting of misalignment tolerances.

19. Further dynamic magnification results from lateral track to side or guide wheel clearance on roller coasters. It is very common for designers to underestimate this magnitude at the design stage and, if subsequent accelerometer or other measurements are not used for confirmation purposes, it may be necessary to presume that wheel cluster and axle fatigue will occur and that a regular inspection programme for such components must be specified.

Use of Dynamic Analysis Software Packages

20. Designers should ensure that the software is suitable for the purpose for which it is employed.

21. When using such software it is important that the specification of the input motions is realistic. For instance, the designer may use an input data assumption of constant acceleration, from start-up, followed by steady motion at maximum speed, when this may be unrealistic after due consideration of the torque / speed characteristics of the drive and control system.

22. Dynamic analysis software may include options to analyse natural frequencies of vibration. This having been said, it is common practice for designers to account for vibration by use of nominal, non-specific, factors. The latter are not always conservative however and, if it is thought that significant natural frequencies might exist, the designer should consider carrying out the extra analysis offered by the software package.

23. For the reasons expressed in the preceding 3 paragraphs, and for other reasons, output results can be significantly affected by the input assumptions. It is therefore important that the designer ensures that a full record of input data is associated with any set of output results. This would be essential for archiving purposes, but also essential for others (such as inspection bodies carrying out design review) who might have to make subsequent reference to the results.

Chapter 3

Calculating loadings

1. This part deals with the calculation of loadings for use in other assessments, e.g. fatigue lives.

Foreseeable loadings

2. These will include:

(a) **Static loadings.** - These should include the weights of both the static and moving parts of the structure (BS 6399-1 and EN 1991-1-1 include advice on weights of materials). The weights of passengers should also be included (see below). Table 3.1 shows typical values which may be assumed, in the absence of more specific data, in relation to the loading of floors and barriers. (Special consideration needs to be given if extreme crush loading can occur. It is not included in the table).

Table 3.1 Imposed loadings on floors and barriers etc.

Location	Vertical imposed loads	Horizontal imposed loads	
		Top rail	Intermediate rail
Floors, stairways. landings, ramps, entrances, exits of rides and structures	3. 5 kN/m^2	0.5 kN/m	0.1 kN/m
Grandstands (including stairways etc.) and parts of rides / structures subject to dense crowds	5.0 kN/m^2	1.0 kN/m	0.15 kN/m
Moving & fixed platforms of rides walked on during loading and unloading but not subject to queues or crowds	The least favourable of 2.0 kN/m^2 or 2 x full passenger load distributed over a realistic area	03 kN/m	0.1 kN/m
No public access	The least favourable of 1.5 kN/m^2 or 1.5kN point load	0.3 kN/m	0.1 kN/m

(b) **dynamic loadings** - (taking account of operating speed, frequency, magnitude and direction of load cycles and the effects of braking, including emergency braking). See also Chapter 2 on Principles of dynamic analysis.

(c) **bracing loads** - resulting from passengers bracing themselves against restraints and other parts of the containment (e.g. footrests).

(d) **out of balance loadings** - (from foreseeable misuse). In the absence of more specific data the unbalanced loadings for use with rotating devices (or parts of devices) may be considered as follows :

i. General stress analysis (as well as considering full load): - A sector comprising 1/4 or 3/4 of the circle occupied;

ii. Overturning analysis: - A sector comprising 1/6 of the circle occupied;

iii. Fatigue analysis: - A sector comprising 1/6 or 5/6 of the circle occupied.

(e) **environmental loadings** (e.g. wind, snow). Useful guidance is given in :

i. Snow loads: BS 6399 -3 & DD ENV 1991-1-3:2003

ii. Wind loads: BS 6399 -2 & DD ENV 1991-1-4:2005

Assessments should consider both in-service and out-of-service conditions. The windiest geographic and topographic locations should be considered when assessing out-of-service conditions. A suitable reduced wind gust speed (at 10 m above ground) of 15 m/s may be assumed for in-service calculations.

(f) It will normally be appropriate to ignore wind loading when calculating fatigue lives, however there are some occasions when wind loading might invoke fatigue loading, particularly for static devices.

3. The minimum passenger weights for calculating static and dynamic loadings should be:

(a) 1.0 kN for each device or part designed to carry one person (except for fatigue calculations). When designed to carry more than one person, or when carrying out fatigue calculations, at least 0.75kN should be used.

(b) 0.40 kN may be used where devices are designed specifically and solely for persons under 1400mm in height and provided this limitation is clearly stated in both the design specification and the Operations Manual.

4. Loads resulting from passengers pushing / pulling or bracing themselves need to be taken into account when designing passenger restraints and other parts of the containment (e. g. footrests), railings and bracing devices within the passenger unit. All significant situations during the ride cycle including loading, unloading and emergency situations may need to be considered.

5. The magnitudes of maximum bracing forces are dependent upon the detailed design of the containment and its relationship to the passengers' body positions and the parts of the body which are exerting force. However, if strength data is not to be taken from a reputable source, bracing forces used in any calculations should never be less than 500 N per person without additional justification.

Wind loading assessment

General;

6. In general wind loads should be based on DD ENV 1991-1-4:2005 or BS 6399 -2. For certain countries outside Europe with extreme meteorological conditions there may be additional local requirements to be taken into account.

7. It should be remembered that the geographical location of an amusement device of nearly any type is not fixed throughout its lifetime. Calculations will normally need to be based on the British (or European) locations having the highest average wind speeds. In the terminology of EN 1991-2-4, an appropriate value for $v_{ref,0}$ is 28 m/s for the reference wind

velocity (i.e. the mean velocity at 10 m above ground of terrain category II averaged over a period of 10 minutes, and having an annual probability of exceedance of 0.02 - commonly referred to as having a mean return period of 50 years). For devices or parts of devices which clearly cannot be re-located an appropriate lower value of reference wind velocity may be abstracted from the Standard.

8. For rides or structures which are less than 20 metres high, if either

(a) the associated risks are not severe; or

(b) a scheme for temporary on-site protection, strengthening or sheltering is specified and verified by the designer for inclusion in the Operations Manual; then

the basic value of the reference wind velocity may be modified by the assumption of a 5 year return period and a reduced temporary factor, i.e

(c) $v_{ref}(p) = 0.85\ v_{ref,0}$ and;

(d) $c_{TEM} = 0.80$

9. For the normal case when the ride or structure (or the particular component being assessed) is not susceptible to dynamic response a value of $c_d = 0.90$ may be used.

10. Where the conditions in the two preceding paragraphs apply, the modified pressures q,,f shown in Table 2.2 result for

(a) $c_{DIR} = 1.0$

(b) $c_{ALT} = 1.0$

(c) $c_t = 1.0$

(d) terrain category III

Wind loads may then be evaluated using the following formula

(e) $Fw = \bar{q}_{ref} . c_f . A_{ref}$

Table 3.2

Pressure $\bar{q}_{ref} = q_{ref} \times c_e(z) \times c_d$ **(kN/m²)**

	for ref wind speed	
Height of the structure	$v_{ref} \leq 15$m/s (in service)	$v_{ref,0} \leq 28$ m/s (out of service)
0 ≤8 m	0.21	0.35
8 ≤ 20 m	0.29	0.50
20 ≤ 50 m	0.40	0.95

11. For rides or structures where:

(a) the associated risks may be severe; and

(b) an adequate scheme for temporary on-site protection, strengthening or sheltering has not been specified and verified by the designer for inclusion in the Operations Manual

the values in Table 3.2 may need to be revised.

Revision will also need to be considered for locations for which:

(a) the basic value of the reference wind velocity exceeds 28 m/s; or

(b) the ride or structure (or the particular component being assessed) is susceptible to dynamic response; or

(c) height above sea level is such that the altitude factor exceeds 1.0; or

(d) topography is affected by an isolated hill, escarpment, valley or feature causing funnelling effects; or

(e) the terrain category exceeds III, such as at exposed coastal or open sites.

12. Since pressure increases with height above ground z, overall forces and overturning moments will need to be calculated either by integration over the surface area or by a suitable piecewise approximation based on pessimistic assumptions. For instance, the total force on an area is safely overestimated by using the wind force per unit area calculated at the highest point of this surface. A corresponding safe overestimate of the overturning moment is found by multiplying this force by the height above ground of the centroid of the surface.

Reduced Wind Loads

13. If the primary assessment shows that the device is not stable or structurally sound under extreme conditions of wind loading then reduced wind loads may be acceptable in the calculations, depending upon the provision of temporary protection or strengthening to the device. These must be demonstrated to be capable of resisting the full wind loading. Instructions regarding this protection strengthening should be included in the Operations Manual

14. It will be necessary to calculate a limiting value of mean wind speed for the device at which the protection / strengthening scheme must be invoked. Advice on recognising or measuring the danger limit should be given.

In Service Wind Loads

15. Parts of some amusement devices may be exposed to more significant wind loading whilst giving rides to the public (e.g. the overturning moment caused by wind loading on the seating unit of a Miami Trip is worse when it is at top dead centre than at bottom dead centre). Since it is customary to close down operations when winds become high, reduced values of wind load may be applied to those configurations which are only experienced in service.

16. In-service conditions may be calculated using a value of 15 m/s for v_{ref} (the reference wind velocity).

(a) This is approximately the mid point of Force 7 on the Beaufort scale (Moderate Gale) when whole trees will be in motion and inconvenience is felt when walking against the wind.

The associated modified pressures $\bar{q}_{ref}$ shown in the middle column of Table 3.2 apply in these circumstances.

Relevant Standards and Other Publications

EN 1991	*Eurocode 1. Actions on structures*
EN 1991-1-1	*Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings.*
EN 1991-1-3	*Eurocode 1. Actions on structures. General actions. Snow loads.*
EN 1991-1-4	*Eurocode 1. Actions on structures. General actions. Wind actions.*
BS 6399	*Loading for buildings.*
BS 6399-1	*Loading for buildings. Code of practice for dead and imposed loads.*
BS 6399-2	*Loading for buildings. Code of practice for wind loads.*
BS 6399-3	*Loading for buildings. Code of practice for imposed roof loads.*

Note: When using Eurocodes designers should ensure that they refer to the current UK national annexe. Eurocodes should not be used unless a current UK national annexe is available.

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Chapter 4
Assessment of fatigue

1. Many amusement devices are designed with the purpose of subjecting the passengers to significant variations in acceleration. This means that lots of safety-critical structural and mechanical ride components experience significant stress fluctuation such that fatigue is the dominant failure mode. For this reason, for such components it is essential that the assessment of fatigue is realistic. It is conventional in Britain, because all equipment is subject to a regime of annual third-party inspections which may involve NDT, to assess fatigue lives. On the basis of the fatigue life, designers and inspection bodies may ensure that component inspection programmes are sensibly tailored

Fatigue life assessment

2. The safety assessment should determine fatigue lives, in terms of ride operating hours, of individual safety critical components which will be repeatedly subjected to stress fluctuations of a magnitude and frequency which could result in fatigue damage.

3. Information on fatigue life assessment is given in:

Table 4.1 Fatigue Standards

BS 7608	for steel structures
ENV 1993 1 9	
BS 8118-1 EN 1999-2	for aluminium structures
BS 2573-2 (=ISO 4301/1)	for machined components

4. In these Standards, to aid fatigue analysis, many welds and other physical features have been grouped into classes according to their construction.

5. Fatigue lives may be determined either by calculation (for those features covered by a suitable method) or by accelerated life tests. When the detail is not identical to one of the standard types, Finite Element Analysis may be a useful technique for calculating stress in complex structural details. [If doubt about the accuracy of calculated stress magnitudes or frequencies in a safety-critical component remains, the designer may need to consider confirmation by test]. Fatigue lives associated with these calculated stresses for non-standard details may then be derived using the "geometric stress range" or "hot spot stress range" as appropriate.

6. An appropriate inspection programme must be devised for all safety critical component details which do not have a fatigue life at least twice the foreseeable operating life of the device. Alternatively, component replacement at or before half of the fatigue life may be specified - however, the designer may need to consider the risks associated with non-compliance.

7. As a guide, fatigue calculations will be needed where the stress magnitude in a component varies with time by more than 10% and the number of repetitions of this variation during its design life is likely to be greater than 20,000. In such cases, the designer may need to take account of:

(a) the maximum value of the nominal principal stress and whether it is compressive or tensile,

(b) the minimum value of nominal principal stress and whether it is compressive or tensile,

(c) the number of times the stress will vary between these extreme values per operating hour.

8. If the same component is also likely to have a significant number of repetitions in one or more smaller stress ranges, the designer should carry out a statistical analysis to determine the effect these smaller stresses is likely to have on the component's fatigue life.

9. The additive effects of different stress cycles should be considered.

10. Since fatigue life is calculated in cycles, a means of readily identifying the number of in-service stress cycles should be specified. (Cycle counters are on the market). Any such system should be tamper-proof and either measure stress cycles directly or provide information from which stress cycles can be easily calculated. Conversion factors for relating cycles to operating hours should be provided.

Designing to increase fatigue life

Minimising stress concentration

11. Fatigue strength is a local rather than a systemic property of a component. Abrupt changes of section should be avoided, particularly in pins and shafts as they act as stress raisers and significantly reduce fatigue life. If a change of diameter or section is unavoidable, it should be made gradually with large fillet radii or run out (15 degree max) to limit the stress concentration.

12. The following are important, but do not make up an exhaustive list of measures to consider when designing to reduce stress concentration:

(a) Mechanical components which have to abut a shoulder with a fillet radius may be provided with a chamfer to eliminate contact with the radius. The chamfering alleviates stress concentration and fatigue damage from fretting.

(b) Slots and grooves e.g. keyways and lubrication grooves may be provided with generous run-out radii, with fillet radii in all corners. Accordingly keys and splines should have chamfers to avoid damaging the radii.

(c) Lugs, brackets, clips, holes, etc. for transportation, stowing, carrying pipes, cables and similar services should be specified at the design stage and positioned to minimise their effect on fatigue life. All effects of these attachment points on fatigue life should be determined.

(d) Other factors to be considered include surface/weld profile, joint configuration, threads etc.

13. Potential stresses involved in frequent erection, dismantling and transportation of mobile devices should be taken into account. Where necessary, the assembly procedure should be specified to reduce the risk of overstressing structural and other components through using inappropriate assembly sequences or practices

14. The importance of, and reasons for, these features should be emphasised and the features toleranced accordingly. For mechanical components the designer should calculate for each design feature a theoretical stress concentration factor value (K_t). Data sheets

giving K_t values for many fundamental geometric parameters such as diameters, fillet radii etc are available (see bibliography)

Specifying surface finish

15. Smooth surfaces may improve the fatigue life of components. Therefore surface finish should be considered in the designer's calculation of fatigue life and may need to feature in the specification. For instance where flame cut blanks are to be used in fatigue-sensitive areas, the specification may not only require the edges to be ground but might also identify the type and direction of the finish required because the direction of grinding can affect fatigue life.

Protecting against corrosion

16. Defects caused by corrosion may act locally as stress concentrators and / or may initiate and accelerate crack propagation. The design should therefore seek to minimise the effects of the environment. Corrosion due to the retention of rainwater or salt water can be reduced by providing drainage and alerting end users to clear drainage areas and holes where necessary.

17. Corrosion may be limited by provision of protective coatings. See, for instance, ISO 12944 and ISO 14713.

18. In some instances, electro-deposition of metals (e.g. hard chrome plating) or hot dip galvanising onto medium and high tensile steels can lead to reduction in fatigue life of the parent metal. The loss in fatigue strength can be largely avoided by shot-peening the material before plating. It is essential that the necessary pre- and post- stress relieving treatments are done whenever there are such risks.

19. The fatigue properties of the materials required and the fabrication techniques to be used should be considered at an early stage in the design process. Materials with outstanding fatigue resistant properties cannot compensate for a poorly designed product. However, the fatigue resistant properties of an otherwise superior design can be undermined by an incorrect choice of material.

20. Where fatigue is a dominant design criterion, which is very often the case with amusement ride components, the specification should take account of material properties such as ductility and notch sensitivity, together with their effect on crack propagation.

21. When British and European Standards relating to fatigue are employed, such as those listed in Table 3.1, conditions on the selection of materials are incorporated and should be followed.

22. For machined components a wider selection of materials is available and the designer should choose one with a (proof stress)/(tensile strength) ratio optimally at 0.75, low notch sensitivity, and adequate elongation, usually not less than 10%

Choosing the fabrication method

23. Fusion welds e.g. gas flame or metal-arc can reduce the fatigue life of components when, for example:

(a) the weld is a cast structure and may have fatigue properties inferior to the parent metal;

(b) the parent metal microstructure can be affected by a wide heat affected zone each side of the weld (Some stainless grades of steel may suffer from weld decay, depletion of chromium at the grain boundaries, which can reduce the physical or corrosion resistant properties);

(c) both the weld metal and the surrounding material may be prone to defects e.g. hot cracks, slag inclusions if the welding process used is inappropriate or incorrectly performed ;

(d) the thermal gradients induced can cause residual stresses leading to reduction in fatigue strength;

(e) the shape of the weld and connected parts may act as a geometric stress raiser, locally increasing stresses.

24. Where welded assemblies may be subject to repeated stresses, careful consideration may need to be given to the siting of welds because welded joints will have shorter fatigue life. The designer may need to specify post-weld heat treatments in order to minimise the effects of welding on fatigue life. The designer should consider having safety-critical components made from a single piece of parent material where it is practicable to do so. The Standards listed in Table 4.1 incorporate more advice on these issues.

Making it easy to examine and test safety-critical components in-service

25. Good design should make it easy to inspect and maintain an amusement device in safe condition once it has entered service. The designer should therefore consider very carefully how it is to be examined, tested and maintained. It is particularly important that safety-critical component details, particularly those having calculated fatigue, corrosion or wear lives less than twice the specified replacement life of the component, are:

(a) **accessible** - there have been many unacceptable cases where safety-critical components have not been examined, tested or maintained because of the amount of dismantling needed to reach them. In some instances, they have been housed inside welded structures

(b) **clearly identified** in the Operations Manual with lifespan and all requirements for maintenance, examination and testing precisely specified. For visual examination and NDT this should include:

i. the maximum period before first examination or test

ii. the subsequent frequency of examination or test

iii. the purpose of the test (type of defect to look for and its likely location);

iv. significant acceptance/rejection criteria.

v. Additionally for NDT this should include:

vi. method and relevant technique;

vii. specification of any initial NDT to be done by the manufacturer to provide reference material in the Operations Manual, e.g. ultrasonic traces or x-ray results showing the original condition of components or structures.

26. While even the best designed devices may have component details which require NDT to give assurance of their continued fitness for purpose, the need for frequent or extensive NDT may indicate a lack of attention to fatigue prevention, or an over-reliance on

tolerance rather than prevention.

Relevant Standards & Other Publications

ISO 12944	*Paints and varnishes. Corrosion protection of steel structures by protective paint systems*
ISO 14713	*Protection against corrosion or iron and steel in structures. Zinc and aluminium coatings. Guidelines.*
EN 1993-1-1	*Eurocode 3. Design of steel structures. General rules for buildings.*
EN 1999-1-1	*Eurocode 9. Design of aluminium structures. General rules. General rules and rules for buildings.*
BS EN 13001-2	*Crane safety. General design. Load effects*
BS 7608	*Code of practice for fatigue design and assessment of steel structures.*
BS 8118-1	*Structural use of aluminium. Code of practice for design.*

Note: When using Eurocodes designers should ensure that they refer to the current UK national annexe. Eurocodes should not be used unless a current UK national annexe is available.

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Chapter 5
Specifying materials

Steels

1. Supporting frameworks should be made from weldable structural steels to BS 7668, EN 10025; or EN 10210. If other steels are used, they should have properties at least comparable to those Standards. Design recommendations for the use of structural steel in buildings are given in BS 5950 and ENV 1993 and their supplements and addenda. These, when used in conjunction with fatigue standards (see Chapter 4) contain useful guidance which is relevant to fairground structures.

2. The deterioration of steel components may be inhibited by providing protection against corrosion using one of the methods described in ISO 12944 or ISO 14713. Hollow section structural steel will be subject to internal corrosion, and the designer should specify what internal corrosion allowance has been used. He should consider whether to specify that the ends be permanently closed to prevent ingress of corrosive fluids. Where excessive corrosion could weaken safety critical parts of the structure, the designer should specify the recommended method and frequency of inspection and this should be entered in the Operations Manual.

Aluminium alloys

3. Particular care should be taken when specifying aluminium alloys for structural use, including decking and lighting features. BS 8118 and ENV 1999 give recommendations for the use of aluminium in all types of structure, including advice on material, loading, design, testing, fabrication and erection, and protection. Suitable weldable alloys are included.

4. The strength of some popular alloys is highly dependent on the heat treatment to which it has been subjected and can be severely diminished by application of heat in the manufacturing process. For safety critical components the designer should specify any restrictions to be applied during manufacture.

5. The designer should keep a record of which alloy has been specified for each component in case repair or replacement is required.

6. Care should be taken when using aluminium with steel because of cathodic corrosion. BS 8118 and ENV 1999 give advice.

Timber

7. Structural use of timber for safety critical components should be limited to the species listed in BS 5268-2 or EN 1995. Both of these Standards also contain design recommendations. Bearing in mind the trade-off between material choice and resistance to decay, the designer needs to take into account where the structure is to be located. He should also advise on categories of materials suitable for repair.

8. Bracing should be provided to ensure that transverse deflections under load do not cause secondary bending stresses in structural members.

9. Connections using nails should not be made in any location where load magnitude or fluctuation is significant. Joints in main trestles and for the secondary members between trestles should be bolted. The holes in the timber should be the same size as the bolts, which should be driven home to ensure a tight fit to minimise water penetration which can

lead to rot.

10. Timber guard rails should be designed to BS 6180.

Plastics and composites

11. Plastics and composites are used, particularly in passenger units, because they give the designer the freedom to make complex shapes.

12. Designers will be aware of the difficulty of designing (and confirming the design safety of) plastic composite safety critical components for structural applications. It is therefore usual to base the design of such components on a steel (or other) framework. If the strength of the framework can be shown to be sufficient on its own, no structural analysis or testing of the plastic shell is required. However, the design specification should, where necessary, allow access for inspection of the framework.

13. The designer may need to take account of:

(a) the properties of the material;

(b) the likely variability created by the manufacturing method, particularly if the composites are hand-laid;

(c) the likely deterioration in the material in service;

(d) the thermal expansion properties (which are relatively large for composites);

(e) the design of the supporting structure to prevent excessive loads at the points of support, taking loading and expansion into account;

(f) the type of fastening most appropriate to the composite used e.g. bolts, rivets, moulded-in inserts or adhesive bonding;

(g) the likely effects of corrosion on attached or moulded-in reinforcing

(h) the possibility of fatigue where there are fluctuating loads.

14. The strength and fatigue properties of plastics are increased by reinforcement. The strength of a composite depends on the strength, orientation, proportion and type of fibre and resin. For instance, the addition of 30% of glass fibres may increase the strength twofold. The maximum fatigue resistance is obtained using laminates with unidirectional fibres. Lesser improvements are achieved with (in order of decreasing effectiveness) 85% unidirectional, cross ply, glass fabric, random short fibre. BS 4994 gives useful guidance for specifying reinforced plastic structures.

15. Plastics and composites differ from metals in a number of significant properties. In particular, they can be significantly affected by both time and temperature, while their visco-elastic nature makes their behaviour under stress more complex. Unreinforced plastics usually have non-linear stress-strain curves up to the yield point while glass reinforced plastics (GRP) are practically linear up to 0.3% strain. Plastics also have much higher creep than metals. Therefore, components under constant load should be designed against creep strength rather than yield strength.

16. The designer should obtain adequate information on the plastics, additives and reinforcements to be used and if necessary consult the manufacturer or another authoritative source of information on the properties of the materials before finalising the specification.

17. Where components made of composites are safety-critical, the designer should make clear that they should only be fabricated by manufacturers who have the facilities,

personnel and procedures to maintain the necessary quality. In particular, the process needs to be adequately specified and controlled to ensure consistent properties in the finished article. The requirements for initial and in-service examinations also need to be specified at the design stage. Particular attention should be given to points of potential high stress created by the shape of the structure and the presence of fittings.

Relevant Standards and Other Publications

ISO 12944	*Paints and varnishes. Corrosion protection of steel structures by protective paint systems*
ISO 14713	*Protection against corrosion or iron and steel in structures. Zinc and aluminium coatings. Guidelines.*
EN 1993	*Eurocode 3.Design of steel structures*
EN 1995	*Eurocode 5. Design of timber structures.*
EN 1999	*Eurocode 9. Design of aluminium structures.*
EN 10025	*Hot rolled products of non-alloy structural steels. General delivery conditions.*
EN 10210	*Hot finished structural hollow sections of non-alloy and fine grain steels. Tolerances, dimensions and sectional properties*
BS 4994	*Specification for design and construction of vessels and tanks in reinforced plastics.*
BS 5268-2	*Structural use of timber. Code of practice for permissible stress design, materials and workmanship.*
BS 5950	*Structural use of steelwork in building.*
BS 6180	*Barriers in and about buildings. Code of practice.*
BS 7668	*Weldable structural steels. Hot finished structural hollow sections in weather resistant steels. Specification.*
BS 8118	*Structural use of aluminium.*

Note: When using Eurocodes designers should ensure that they refer to the current UK national annexe. Eurocodes should not be used unless a current UK national annexe is available.

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Chapter 6
Designing foundations, supports and structures

General design requirements

1. The following paragraphs refer to a number of British and European Standards which are normally the most appropriate for use in the UK. The designer may need to consider other national standards and codes for structural design, of which there are many.

2. General information on designing structures is given in ENV 1991, BS 5950 and EN 1993 for steel; and BS 8118 and EN 1999 for aluminium; BS 8110 and EN 1992 for concrete; BS 5268 and EN 1995 for timber.

Foundations

3. Where there are to be purpose made foundations, the designer should consult the prospective controller to determine the siting of the structure. From that he may establish appropriate site-specific loading and environmental conditions. The designer will need to decide the extent of any site investigations. The designer should calculate the direction and magnitude of the forces which will be applied to the ground by the supporting structure. The foundations shall be designed, in accordance with BS 8004 or EN 1997-1, to withstand these forces. Where the designer and foundation constructor are from different countries, account must be taken of potential confusion from different units of measurement, drawing projections and other conventions (e.g. compass bearings).

Support and Stability

4. Outriggers or other means may need to be used to maintain the stability of the device. Calculations and / or tests should demonstrate, in the worst operational and non-operational conditions including during erection, the ability to resist overturning, sliding and lifting. (Suitable calculation loads are given in Chapter 3 above). Advice, to be included in the Operations Manual, on minimum ground bearing areas for each designated point of support should be based on the above calculations taking into account likely ground conditions.

5. The designer should supply information on the designated positions at which pressure is to be transferred from the device to the ground and on the size and direction of the forces imposed. He should also give recommendations for levelling, packing and securing of the device as appropriate. These matters should form part of the instructions for safe erection, to be included in the Operations Manual.

6. The use of packing should be minimised. Where it is permitted, the maximum packing height at various points should be specified, together with any necessary precautions. Calculations (and subsequent tests) should investigate the likelihood of movement of the device off its packing. Where this could be a problem, advice on precautions, e.g. anchorage, should be included in the Operations Manual.

7. Hydraulic jacks should not be used as supports, except during buildup, unless compensation for leakage can be guaranteed. The permissible out of level tolerance should be specified by the designer and included in the Operations Manual, together with the other advice given above.

8. Where a trailer with road wheels and running gear forms part of the device, provision should be made to ensure that no part of the dead, imposed or dynamic loads is

transmitted to the foundations by the wheels or running gear.

9. Where a vehicle or trailer chassis forms all or part of the stationary framework, the designer should make sure that it will withstand both the static and fluctuating stresses imparted during erection, use, dismantling and transportation. The fatigue life of critical chassis components should be established and the methods and frequency of examination specified.

Structures

10. The designer should calculate the fatigue lives of all safety critical components of the structure. Recommended methods and frequencies of examination should be based on the calculated fatigue lives and included in the Operations Manual.

11. Normal structural design methods should be used for those parts which are not dominated by fatigue.

Ancillary equipment

12. The design should ensure that ancillary equipment and structures will be safe under foreseeable operating conditions. For example, calculations should demonstrate that backdrops and lighting displays will be strong and serviceable enough to withstand predictable wind loadings, wear and tear associated with regular assembly and dismantling where appropriate, and capable of being adequately secured at all times. Guidance on the assessment of wind effects is given in Chapter 3, paragraphs 5 to 15.

Joining the parts

Non-welded joints

13. Bolts for structural connections should conform with EN 1993-1-1.

14. The designer should determine the maximum loads arising in bolted joints and specify on the assembly drawings and maintenance schedules the pre-load torque to which they should be tightened. This is particularly important for load-bearing rotating assemblies such as slewing rings. Nuts on critical assemblies should have a suitable locking device.

15. Safety critical bolts which are subjected to repeated stress fluctuations should be assessed with respect to fatigue life. Recommended methods and frequencies of examination and / or replacement should be based on the calculated fatigue lives and included in the Operations Manual. (Bolts, studs and rivets are difficult to inspect by NDT in situ and replacement is a safer way of ensuring continued suitability for service).

Welded joints

16. Load-bearing welds in steel structural parts should be designed in accordance with BS 7608 or EN 1993-1-9. Where fluctuating loads are not significant BS 5950 may be used. Welding of steels not covered by these Standards, e.g. wear-resistant or hardenable steels used in specific applications, such as pins, shafts and tracks should not be specified unless consideration has been given to the metallurgical effects. Where the resultant quality of a welded joint in steel could be significant then ISO-25817 could be relevant.

17. Load-bearing welds in aluminium structural parts should be designed in accordance with BS 8118 or ENV 1999. Where the resultant quality of a welded joint in aluminium could

be significant then ISO-10042 could be relevant.

18. Weld specifications (certainly of every safety critical component) should always be shown on manufacturing drawings. Symbolic representation should comply with EN 22553.

19. Welding procedures, when safety critical components are involved, should be approved in accordance with ISO 15607 - ISO 15614 and welders approved in accordance with EN 287-1 or ISO 9606-2.

Relevant Standards & Other Publications

ISO 5817	*Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections.*
ISO 10042	*Arc-welded joints in aluminium and its weldable alloys. Guidance on quality levels for imperfections.*
EN 287-1	*Qualification testing of welders. Fusion welding. Steels*
EN 1991	*Eurocode 1. Actions on structures.*
EN 1992	*Eurocode 2. Design of concrete structures.*
EN 1993	*Eurocode 3. Design of steel structures.*
EN 1993 -1-1	*Eurocode 3. Design of steel structures. General rules and rules for buildings.*
EN 1995	*Eurocode 5. Design of timber structures.*
EN 1997-1	*Eurocode 7. Geotechnical design. General rules.*
EN 1999-1-1	*Eurocode 9. Design of aluminium structures. General rules. General rules and rules for buildings.*
EN 22553	*Welded, brazed and soldered joints. Symbolic representation on drawings.*
BS 5268	*Structural use of timber.*
BS 5950	*Structural use of steelwork in building.*
BS 7608	*Code of practice for fatigue design and assessment of steel structures.*
BS 8004	*Code of practice for foundations.*
BS 8110	*Structural use of concrete.*
BS 8118	*Structural use of aluminium.*
Note:	When using Eurocodes designers should ensure that they refer to the current UK national annexe. Eurocodes should not be used unless a current UK national annexe is available.

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Chapter 7
Mechanical systems

Hydraulic and pneumatic

General

1. The designer should assess all modes of failure which could affect passenger safety, taking particular account of all the forces acting on cylinders, hoses and other components during normal use, erection, dismantling, maintenance and repair.

(a) Advice on hydraulic systems is given in ISO 4413 and EN 982.

(b) Advice on pneumatic systems is given in ISO 4414 and EN 983

(c) Principles and presentation for mechanical, hydraulic, pneumatic and other diagrams are given in BS 5070-3.

(d) Graphic symbols and circuit diagrams for fluid power systems (both hydraulic and pneumatic) and components should be in accordance with ISO 1219-1 (identical to BS 2917-1) and ISO 1219-2.

2. The design specification should meet the following general requirements where necessary:

(a) all components should operate within the manufacturer's specification

(b) all parts of the system should be protected against overpressure

(c) components requiring maintenance should be accessible

(d) where operating pressures and flow rates are safety critical they should be specified by the designer and set by the manufacturer so that they can only be adjusted within a pre-set range

(e) pressure gauge ports (or gauges protected from in-service damage) should be fitted in order to allow monitoring of the system

(f) flexible hoses should be of suitable length to prevent over-stress and should be protected from accidental damage

(g) fluid level indicators should be fitted.

Specific requirement for hydraulic systems

3. The risk of fluid contamination and heat build up should be minimised by carefully siting pumps, enclosing fluid reservoirs and providing efficient strainers, filters and coolers.

4. Hose rupture valves or restrictor valves should be provided directly on the support side of all cylinders where a rupture could affect the safety of the device, particularly where hydraulic pressure is used to raise any part of it. Hose rupture valves should not cause shock loads which could overstress the structure.

5. Other facilities should be provided to allow the elevated part to be lowered safely after operation of a hose rupture valve.

Specific requirements for pneumatic systems

6. Pneumatic systems operating above 0.5 bar over atmospheric pressure may fall within the scope of the Pressure Equipment Regulations 1999 or the Pressure Systems Safety Regulations 2000. There is an Approved Code of Practice to the Regulations and HSE has also published guidance. The Simple Pressure Vessels Regulations 1991 (amended in 1994) may also be relevant.

7. Where necessary on safety-critical circuits a filter, drain, regulator and lubricator should be provided in the supply line and additional drain taps provided where condensate can be collected and released safely.

8. Where necessary, pressure relief valves, hose rupture valves and / or air fuses should be provided to protect the system from over-pressurisation. The operation of these valves should not lead to unsafe operation of the device or to other danger.

9. Exhaust ports should be positioned or fitted with silencers such that the escaping air does not lead to danger.

Couplings

Rotating shaft couplings

10. These should have an adequate service factor to transmit the design power reliably. This should take account of the anticipated daily operating hours together with any foreseeable shock loadings. A torsional analysis should be made before specifying couplings which may be subject to substantial shock, vibration or torque fluctuations.

11. Where proprietary flexible couplings are used, the specification should be consistent with the manufacturers' instructions.

12. Suitable protective devices should be provided if failure of a coupling could lead to injury - for instance, covers should be provided if there is a risk of ejection of parts or entanglement.

13. Where the calculated risk of a coupling failure which could cause loss of control of a passenger unit is unacceptable, a secondary system may be fitted or an inspection and replacement programme specified. Any secondary system should not come under load during normal operation and should be designed to withstand any breakaway loadings which may result from the coupling failure.

Hinge pin pivot couplings

14. Where a coupling consists of a pivot pin (or shaft), the pin should be an interference fit in one of the components only, allowing the other components(s) to rotate on the fixed pin. This has the advantage that one of the components does not need a bearing surface. (For ISO limits and fits see ISO 286). Alternative means (i.e. other than by an interference fit requiring some precision) of stopping pin rotation with respect to one of the coupled components may be used.

15. If the risk of coupling failure cannot be reduced to an acceptable level, other secondary means (e.g. a back up retaining device) should be provided.

16. All bearing surfaces should be provided with a means by which the bearing can be adequately lubricated.

17. A pivot pin supported at both ends experiences smaller bending stresses than in a

cantilever design. In both types the detail of the design should be carefully considered and calculation of bending as well as shear stresses should be carried out. Fluctuating stresses need to be assessed for fatigue life. This recommendation also applies to wheels of track guided rides which are likely to be mounted on stub axles and to be subjected to large forces. (EN 1993-1-8 gives advice on bending stresses in pin joints).

18. If failure of a single axle on a track guided ride would result in a passenger unit leaving the track, the specification should ensure (either by providing adequate design life, by an inspection and replacement programme, or otherwise) that failure in service cannot occur.

Ball and socket couplings

19. Many of the proprietary ball and socket couplings available are designed for towing trailers behind vehicles. However, some manufacturers have test data covering fatigue loading in a variety of circumstances. Before using proprietary couplings, the designer should check with the manufacturer supplier that they will be suitable for the intended use.

20. If the risk of coupling failure cannot be reduced to an acceptable level, other secondary means (e.g. a back up retaining device) should be provided.

21. Couplings should be designed to have provision for effective lubrication of the bearing surface.

22. When replacing ball and socket couplings, the complete assembly should be renewed to prevent the possibility of mismatch due to wear or incorrect sizing.

23. Some proprietary ball and socket couplings have in-built, readily visible, wear gauges. Where using types in which this is not present, the designer should specify the safe wear limits and the means and frequency of checking them.

Relevant Standards and Other Publications

ISO 286	ISO system of limits and fits
ISO 1219-1	Graphic symbols and circuit diagrams for fluid power systems and components. Specifications for graphic symbols.
ISO 1219-2	Fluid power systems and components. Graphic symbols and circuit diagrams.
ISO 4413	Hydraulic fluid power. General rules relating to systems.
ISO 4414	Pneumatic fluid power. General rules relating to systems.
EN 982	Safety of machinery. Safety requirements for fluid power systems and their components. Hydraulics.
EN 983	Safety of machinery. Safety requirements for fluid power systems and their components. Pneumatics.
EN 1993 -1-8	Eurocode 3. Design of steel structures. Design of joints.
BS 5070-3	Engineering diagram drawing practice. Recommendations for mechanical/fluid flow diagrams.

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Chapter 8
Controls: general requirements

1. All operating controls should be:

   (a) clearly visible to the Operator

   (b) easily distinguishable from each other

   (c) readily accessible to the Operator

   (d) easy to operate

   (e) clearly marked to show the function and mode of operation. All markings should be permanent and conform to recognised standards. Written markings should be in a language agreed between the user and the supplier.

2. The Operator's working position should be:

   (a) be safe (and have safe access)

   (b) make it easy to control the ride

   (c) have adequate illumination

   (d) give, where possible, an unobstructed view of all areas of operation.

   (e) take into account environmental aspects e.g. temperature, vibration and noise

3. The design also should take account of any need for the operator and attendants to communicate, between themselves and where necessary with the public e.g.

   (a) visibly

   (b) by phone/ intercom

   (c) public address

   (d) through the ride control system (such as 2-button operating systems).

4. Controls designed to be operated by passengers should:

   (a) be clearly marked, in a language agreed with the controller, to show their functions;

   (b) be accessible to all passengers within the designated size limits;

   (c) not present a risk to passengers through their positioning or use.

   (d) should not be foreseeably capable of causing injury to passengers either directly (e.g. by trapping hands or fingers, electric shock, etc) or by causing any controlled device to malfunction or operate inappropriately

   (e) only be operable by passengers when it is safe for them to do so

   (f) never override an operator selected control input where it would be unsafe to do so.

   (g) Be able to be muted or over-ridden by the operator if necessary.

5. The designer should anticipate how controls could fail or be misused as well as the possibility of operator error and ensure that there is no significant risk from such events.

6. The design should indicate how equipment is to be protected, installed and operated to prevent danger.

7. Controls located in public areas and accessible to the public should be tamper -

proof where necessary to prevent misuse.

8. Any necessary diagrams and instructions should be provided in the Operations Manual.

9. Guidance on control panels, displays etc. is given in EN 894.

10. Design of stop controls is given in Chapter 9.

Relevant Standards & Other Publications

EN 894-1	*Safety of machinery. Ergonomics requirements for the design of displays and control actuators. General principles for human interactions with displays and control actuators*
EN-894-2	*Safety of machinery. Ergonomics requirements for the design of displays and control actuators. Displays*
EN 894-3	*Safety of machinery. Ergonomics requirements for the design of displays and control actuators. Control actuators*

Chapter 9

Safety-related control systems

Introduction

1. Most amusement devices contain control systems, the fundamental elements of which are input sensors such as switches and proximity devices, control logic for processing input signals and determining output signals, and output actuators such as brakes and motors. Many of these control systems perform functions such as emergency stop, interlocking on passenger restraints and access gates, block-zone control, and braking.

2. A control system in an amusement device should be regarded as being safety-related if its correct functioning contributes to reducing any risk to a tolerable level, or is necessary to maintain or achieve safety. The functions carried out by a safety-related control system are therefore termed 'Safety Functions'. Generally, safety functions maintain or achieve a safe state by preventing the initiation of a hazardous situation, or by detecting its onset and initiating an appropriate response .

3. This aspect of overall safety associated with a control system operating correctly in response to its input signals is known as 'Functional Safety'. It is distinct from safety associated with exposure to the energy source (e.g. electricity) used in the control and power systems of an amusement device,

4. Safety-related control systems should be designed and configured to:

(a) perform the safety functions that are necessary to maintain or achieve a safe state (or mitigate the consequences of a hazardous situation) ; and

(b) perform each safety function with sufficient integrity (bearing in mind the consequences of any failure)

5. The principles covered by this Chapter apply to safety-related control systems implemented in a range of technologies, including electrical, electronic, programmable electronic, mechanical, pneumatic, hydraulic and manual systems. It describes the general principles that should be adopted in the design of safety-related control systems, and also discusses application of the following relevant standards:

(a) IEC 62061 – Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems

(b) EN 954 –1 – Safety of machinery – Safety-related parts of control systems – Part 1. General principles for design.

(c) IEC 61508 – Functional safety of electrical/electronic/programmable electronic safety-related systems (Parts 1-7)

6. Brief reference is also made to the future ISO 13849-1 – Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design, which was being developed at the time of publication.

7. Regardless of which particular standard is applied, the designer should take full account of the level of risk reduction that the safety-related control system is required to achieve. This is because the required level of risk reduction will have a significant influence on the design techniques needed to ensure that the performance in terms of reliability and tolerance to faults is adequate.

8. Failures that occur in a safety–related control system can be classified as either random hardware failures or systematic failures. Random hardware failures arise as a result of degradation mechanisms within the hardware, which as their name suggests occur at an unpredictable point in time. Systematic failures on the other hand are associated with deficiencies built in to the hardware or software, typically caused by errors in the requirements specification, or due to inappropriate selection, design or implementation of hardware or software. As systematic errors are deterministic to a certain cause, simulating the failure cause should repeatedly induce them.

General Principles

9. The design characteristics for reliability and fault tolerance of a safety-related control system should stem from the design risk assessment carried out on the amusement device in accordance with Chapter 1. This assessment will identify aspects of the device's operation that create risks that may need to be reduced to a tolerable level.

10. Designers may implement a range of protective measures to reduce the risk, many of which will not involve the use of safety-related control systems. For example, the physical dimensions of passenger restraints are important factors in minimizing the risk of passenger ejection, and the provision of platforms and walkways will reduce the risk of falls from height. However, in many cases risks cannot be reduced to tolerable levels without incorporating safeguards that rely on the correct operation of safety-related control systems. In this case, the designer needs to understand and assess the amount of risk reduction that these systems are required to contribute, and their consequential reliability and fault tolerance capability.

11. The more critical the role played by a safety-related control system, the more reliable and resistant to faults it should be. This property is described as the 'Safety Integrity' of the system, which is an indication of the degree of assurance or confidence that it will perform the required safety function(s) under all stated conditions within a stated period of time. An adequate level of safety integrity may be achieved by a combination of:

(a) the reliability of the hardware, software, and human operator; and

(b) the way the parts are combined in the design of the control system; and

(c) the use of diagnostic and proof testing techniques; and

(d) the use of other design techniques that avoid systematic failures and/or control systematic faults.

12. The designer should identify all safety functions that are to be performed by the safety-related control systems and then determine the required safety integrity of each. This specification is known as the 'Safety Requirements Specification' and is fundamental to the achievement of safety by design. The overall process is illustrated in Figure 9.1

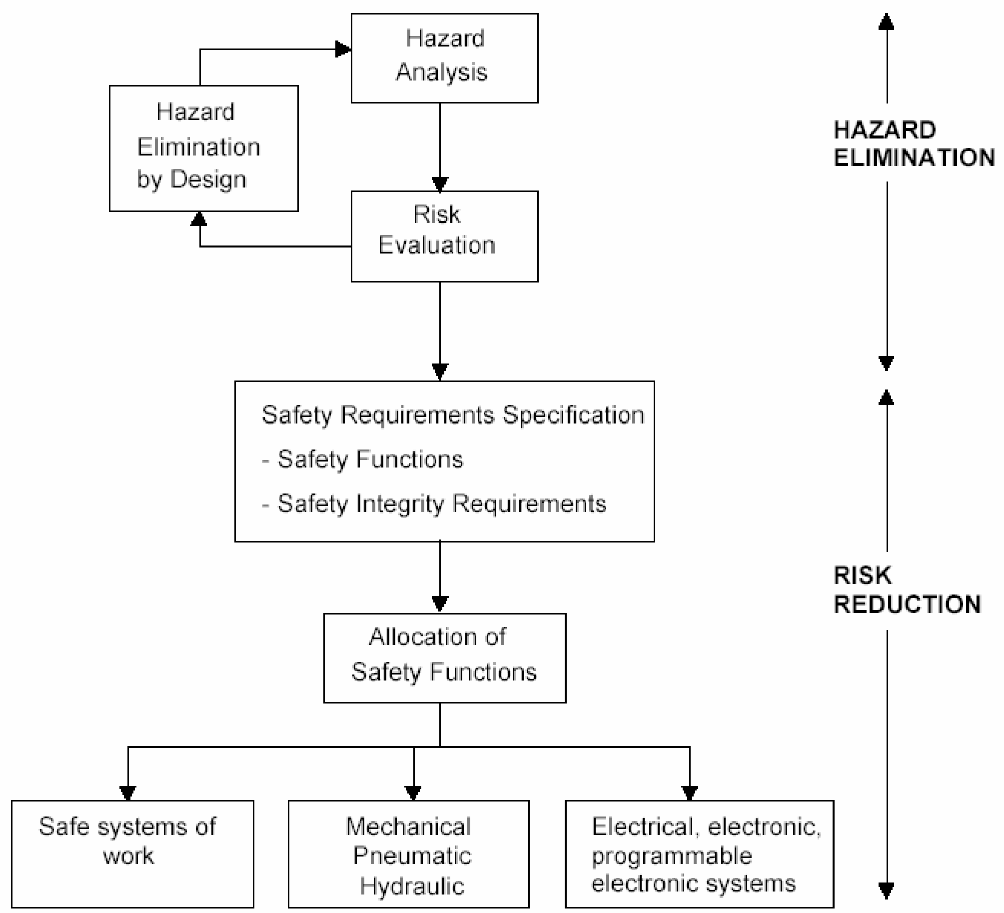

Figure 9.1 The risk control process

13. In designing a safety-related control system to achieve a level of safety integrity that is commensurate with its required contribution to risk reduction at the amusement device, the following require consideration:

(a) The reliability of the equipment and any human actions that form part of the safety-related control system;

(b) Use of techniques such as redundancy, diversity, monitoring, and automatic diagnostics – these are design techniques that can often be an effective means of achieving adequate safety integrity;

(c) How to prevent, as far as possible, systematic faults being introduced during the specification, design or manufacture of hardware and software (e.g. software 'bugs', incorrectly specified components or faulty wiring);

(d) The design of any human interfaces;

(e) How to incorporate design features which may help the control system to recover from faults during operation (e.g. program sequence monitoring);

(f) The behaviour of the safety-related control system under fault conditions (failure modes);

(g) How to test the safety-related system(s) initially to show, as far as possible, that there are no design, manufacturing or installation faults before the amusement device is put into operation;

(h) How to design periodic test and inspection procedures for the safety-related control system(s) for the lifetime of the amusement device to show that no part (including both hardware and software) has changed or deteriorated beyond reasonable limits.

14. These issues should be taken into account for all elements of the safety-related control system, including hardware, software, the way that parts are combined during integration, and any humans on whom the functionality of the system may rely. It should be recognised that all these elements may contribute towards the safety integrity of the individual safety functions and the performance of each element therefore needs to be considered when assessing safety integrity.

15. The following points aim to assist in the process of designing safety-related control systems for amusement devices. They are applicable to new devices, devices being refurbished to present day standards and to older devices being reassessed for the purpose of improving safety.

(a) Identify the hazards occurring at the device, taking into account the hazards that arise in normal operation, during maintenance, and in foreseeable abnormal conditions such as break-down.

(b) Assess the risks from the device. If the risks are determined to be unacceptable, consider designing them out. If this is not possible, determine the risk reduction measures required to reduce the risks to a tolerable level (see Chapter 1).

(c) Allocate safety functions to appropriate combinations of risk-reduction measures, such as positioning, fixed guards, passenger restraints, speed and acceleration control, anti-collision mechanisms, and emergency stops.

(d) Determine which of these risk reduction measures require a safety-related control system.

(e) For each safety function, determine the contribution required from the safety-related control system to achieve the necessary level of risk reduction.

(f) Draw up the safety requirements specification that assigns a required safety integrity to each of the safety functions. The required safety integrity is a measure of the target dangerous failure rate, which is based on the tolerable risk determined as part of the risk assessment process.

(g) Design the safety-related control system. The design process should include consideration of the consequences of failures, which may require the application of reliability analysis techniques such as Failure Mode and Effects Analysis (FMEA), reliability block diagrams, cause consequence analysis, and fault tree analysis. The design should consider failures within purpose built control units, such as electronic motor drives, as well as those in circuitry external to the drives.

(h) Validate the design to ensure that it meets the requirements of the Safety Requirements Specification. Document the process so that anyone who needs to can understand how and why the system meets the safety requirements.

16. Designers should provide information on an appropriate in-service maintenance regime incorporating inspections, tests and any required component replacement schedules. To maintain safety integrity, all safety-related control systems should be tested regularly as part of a preventative maintenance strategy.

17. For any particular safety-related control system, the frequency of testing should be

determined taking into account:

(a) the safety integrity requirements;

(b) the target dangerous failure rate;

(c) the reliability of the component parts;

(d) the degree of fault tolerance; and

(e) the diagnostic capabilities of the safety-related control system.

Programmable Safety-Related Control Systems

18. Some amusement devices have control systems that incorporate programmable electronic systems such as programmable logic controllers (PLC), embedded microcontrollers and microprocessors, and smart sensors. The cost, flexibility and configuration advantages of using such devices are well known, but considerable care should be taken if it is proposed to use programmable electronic systems for implementing safety functions.

19. As with any safety-related control system on an amusement device, those that incorporate a programmable electronic system need to perform the required safety functions with a suitable degree of safety integrity. This will be influenced to a large extent by the programmable electronic system’s susceptibility to random hardware failures, and also to systematic failures within its hardware and software (operating and application).

20. As the failure modes of programmable electronic systems are not well defined and their behaviour under fault condition cannot be readily determined, safety-related control systems incorporating such technology must be regarded as complex systems. This classification is a fundamental factor in the selection of which standard to apply to the design of the safety-related control system (see fig.8.2).

21. Although they may be adequate for performing non-safety-related control functions on amusement devices, general-purpose programmable electronic systems such as PLCs should not be assumed to be suitable for use in safety-related control systems. To determine their suitability for implementing safety functions, the performance of the overall safety-related control system would need to be assessed against relevant standards, which might indicate that the required safety integrity can only be achieved by adopting additional measures to protect against failure of the hardware and software of the programmable electronic system. Alternatively, the safety functions could be performed by supplementary control circuits that do not depend on the correct operation of the PLC.

22. In the absence of additional measures being used, the safety integrity of any PLC or similar programmable electronic system used in a safety-related application should equal or exceed to that of the most critical safety function that it performs. This also applies to the application software (e.g. ladder logic, function blocks) or configuration of such devices.

23. Programmable electronic systems are available that have been specifically designed and assessed for use in safety-related applications by following a rigorous and systematic design approach such as that offered by IEC 61508 . Their designs typically incorporate enhanced redundancy, diagnostic and monitoring techniques to reduce the likelihood and impact of random hardware failures, and diversity to reduce the likelihood of systematic errors inducing common cause failures.

24. Measures should be taken to ensure that software for programmable electronic systems used in safety-related applications does not contain systematic faults. Since it is

generally recognised that software cannot be tested with sufficient confidence to detect all such faults, software developers should minimise the likelihood of errors being introduced during the specification and development of the software by ensuring that the project is well managed within a structured framework. This will include progressive verification, validation and testing of the software components throughout the development cycle including any final development work during commissioning activities. Compliance with IEC 62061 and IEC 61508-3 (Software requirements) will demonstrate that good practice has been followed.

25. Within this framework, the accuracy and completeness of the initial specification for the requirements for safety performance in the control system is of fundamental importance - if the initial specification is deficient, the follow-on stages in the development cycle may not prevent systematic faults from being inadvertently introduced.

26. If the end-user has the facility to alter the application software, rigid procedures to control, assess and validate any changes are crucial. Although programmable electronic systems can make the physical task of modifying a safety-related control system relatively easy compared to wiring modifications in a hard-wired safety-related control system, skills and competencies in machinery safety issues are still vital. Modifications should only be undertaken by persons who possess the competencies that enable them to understand the implications of their actions.

27. If a field-bus system is to be incorporated into a safety-related control system, the overall system should satisfy the safety integrity requirements of each safety function. Field-bus systems suitable for transmitting safety-related data would have typically been designed and assessed for use in safety-related applications by following a rigorous and systematic design approach such as that of IEC 61508. The safety integrity capability of a field-bus system should equal or exceed that of the most critical safety function for which it transmits safety-related data.

28. Although a programmable electronic system that has been designed and assessed specifically for use in a safety-related control system may be certified to a particular safety integrity, it is the risk reduction capability of the overall safety-related control system that should be checked against the Safety Requirements Specification during validation. A component part intended for use in a safety-related control system is only effective if the overall system has been appropriately designed, integrated and validated, all of which require specific competencies.

29. It is essential that work on the specification, design and development of programmable safety-related control systems takes full account of the concepts of capturing safety requirements; safety validation; safety-related system architecture design, hardware and software realisation; and project safety assurance.

Non-Programmable Safety-Related Control Systems

30. This type of safety-related control system does not contain programmable electronic systems, although it is recognised that systems implemented in non-programmable technologies can actually be quite complex in nature. They include electromechanical relay-based systems, hydraulic and pneumatic systems, and mechanical systems that can be assessed using deterministic principles.

31. The general principles for the design of these systems are similar to those used for programmable electronic systems. This is because the requirements should be based on a fundamental assessment of the risks created by the device and the extent to which the

safety-related control system is needed to reduce those risks to a tolerable level, taking into account all other measures taken to control the level of risk.

32. In many cases a safety-related control system based on programmable electronic systems will also comprise non-complex electrical and electronic parts such as interlocking switches and interposing relays. Prior to integrating such parts, the system designer must be able to fully determine whether their application will achieve the appropriate level of safety integrity.

Use of Standards for Safety-Related Control Systems

33. Guidance on the processes and procedures appropriate to the design and development of electrical, electronic and programmable electronic (E/E/PE) technology based safety-related control systems is set out in the basic safety publication IEC 61508, which is regarded as the authoritative good practice in this field. It uses the Safety Lifecycle model to indicate the measures that should be applied from the conceptual design phase through to decommissioning, describing both quantitative and qualitative methods of control system analysis. Although IEC 61508 has been formally adopted across Europe, it is not actually harmonised to a specific Directive.

34. As a basic safety publication, IEC 61508 is intended to be used by IEC technical committees during the development of sector or product standards that have E/E/PE safety-related system considerations. IEC 62061, which is a machinery sector implementation of IEC 61508, provides a framework for designers of E/E/PE safety-related control systems for machines to achieve functional safety. The scope of IEC 62061 is applicable to E/E/PE safety-related control systems of any complexity, including high complexity systems that incorporate programmable electronic systems. As with IEC 61508, it has also been adopted across Europe, but in addition it has been harmonised under the Machinery Directive.

35. EN 954–1, which is also harmonized under the Machinery Directive, provides criteria by which the safety-related parts of control systems based on all operating media can be categorised according to their fault resistance and behaviour under fault conditions. Although the scope of EN 954-1 does not exclude complex safety-related control systems such as those incorporating programmable electronic systems, the standard is most applicable to low complexity safety-related control systems, i.e. those in which the failure modes of components are well defined and the behaviour of the system under fault conditions can be completely determined.

36. Further justification for restricting the application of EN 954-1 to low complexity systems is based on the fact that it does not consider systematic failures, which tend to be increasingly significant in complex systems. Also, it does not provide information on validation techniques for when programmable electronics are used in the design of safety-related parts of control systems, instead referring to other standards such as IEC 61508.

37. Although the exclusion of amusement devices from the scope of the Machinery Directive means that harmonised standards such as EN 954-1 and IEC 62061 have no formal status, they are nevertheless a useful source of guidance for the design of safety-related control systems for amusement devices. Amusement device designers should therefore decide on the appropriate standard that can be applied to the safety related control circuits, with the flow chart in Figure 8.2 aiding this decision.

EN 954-1

38. This Standard categorises safety-related control systems, in total or in part,

according to their resistance to faults and their subsequent behaviour in the fault condition. The resistance to faults is determined by the reliability of component parts and the way in which they are combined in the design. The structural arrangement governs the ability of the safety-related control system to perform its safety function(s) after a fault has occurred

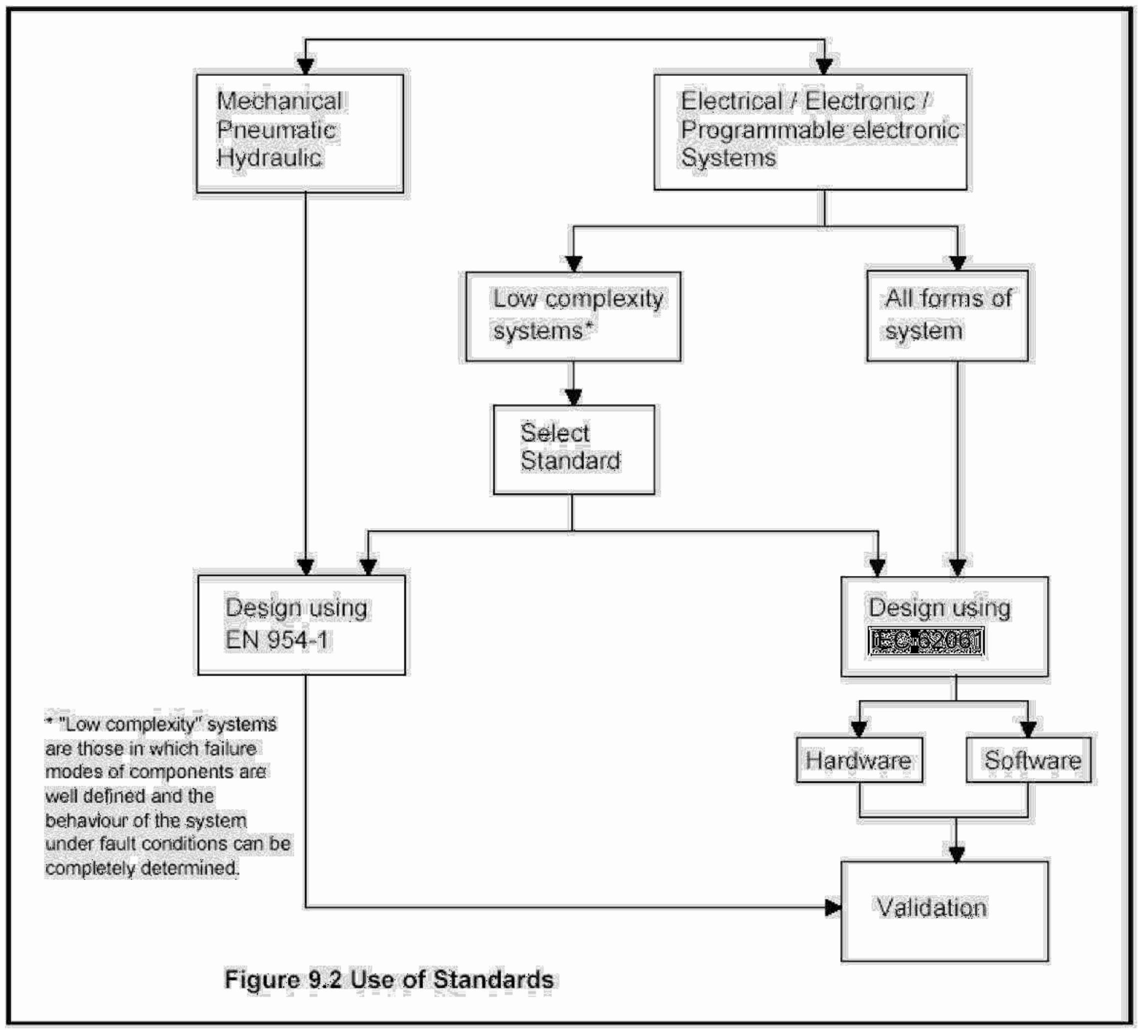

Figure 9.2 Use of Standards

Categories of control systems used in EN 954-1

39. There are five main categories of performance of safety-related parts of control systems in accordance with the standard, which are summarised in Table 9.1 below:

Table 9.3 EN 954-1 Safety Categories	
Category	Basic Requirements (For full requirements see clause 6 of EN 954-1: 1996)
B	Use of good engineering principles
1	Use of well-tried components and principles (reducing the probability of failure)
2	Incorporates a safety function check at machine start-up and may also be checked periodically (safety monitoring) A single fault may lead to the loss of the safety function
3	A single fault will not cause the safety function to fail (redundancy of hardware)

Table 9.3 EN 954-1 Safety Categories	
4	A single fault will not lead to a loss of the safety function. The single fault is detected at or before the next demand upon the safety function, or an accumulation of faults will not lead to a loss of the safety function.

Application of EN 954-1

40. It is important to bear in mind that safety-related parts of control systems may not neatly fit into a single category, particularly if they use different energy sources - a control system can incorporate electrical, electronic, programmable electronic, pneumatic or hydraulic devices.

41. Categories should not be regarded as hierarchical with regard to safety. For example, a single positively operated safety switch element that has been manufactured to a published safety standard might, itself, meet the requirements of Category 1, but not the criteria for higher categories. However, its level of safety performance could be considered at least as high as technologies with structures that meet Categories 2 and 3, but for which the component reliability is inferior in comparison. The selection of categories for the safety functions listed in the rest of this Chapter is therefore a matter of judgment that should be part of a risk assessment (see Chapter 1) and failure analysis.

42. The technical report PD CR 954-100: 1999 provides further guidance on use and application of EN 954-1, whilst ISO 13849-2 (effectively part 2 of EN 954) covers the process of validation of the safety-related parts of control systems of the machine.

Future of EN 954-1

43. EN 954-1 will at some point in the future be replaced by ISO 13849-1, which also applies to safety-related parts of control systems based on all operating media.

44. ISO 13849-1 introduces the concept of a ‘Performance Level’, which is a hierarchical and quantitative measure of the ability of a safety-related part of a control system to perform its associated safety function.

45. There are 5 discreet performance levels (a-e), each corresponding to a range of probability of dangerous failure per hour of the safety-related part of the control system.

46. The Performance Level of a safety-related part of a control system is a function of several parameters, including structure (EN 954-1 category classification), component failure rates and diagnostic capability.

IEC 62061

47. Guidance on the processes and procedures appropriate to the specification, design and validation of machinery safety-related control systems implemented in E/E/PE technologies is published in IEC 62061, which applies the principles of IEC 61508 to machinery applications.

48. IEC 62061 contains advice on the system hardware and software architectures aimed at achieving an adequate level of safety integrity. A quantitative analysis concept that was first introduced in IEC 61508 is that of Safety Integrity Levels (SILs), which specify the target failure values in terms of probability of a dangerous failure per hour and probability of failure to perform on demand.

49. Although IEC 61508 considers SILs ranging from SIL1 to SIL4, the scope of IEC 62061 does not extend to SIL4 - the highest level of safety integrity - as it is not considered relevant to the risk reduction requirements normally associated with machinery.

50. Furthermore, IEC 62061 quantifies SILs solely in terms of a failure rate (for continuous mode and high demand rate safety functions) and not in terms of a probability of failure on demand (for low demand rate safety functions), since the low demand mode of operation is not considered to be relevant for machinery applications.

51. Table 9.4 shows the range of probability of dangerous failure per hour for each value of SIL relevant to IEC 62061.

Table 9.4 IEC 62061 Safety Integrity Levels	
SIL	Probability of a dangerous failure per hour
4	Not applicable
3	$\geq 10^{-8}$ to $<10^{-7}$
2	$\geq 10^{-7}$ to $<10^{-6}$
1	$\geq 10^{-6}$ to $<10^{-5}$

52. The required SIL of a safety function is determined by the initial risk assessment, the analysis of the amusement device safety requirements and the level of risk considered tolerable in the specific application. The safety function will need to have a SIL value that reduces the initial risk to a level that is at least as low as this tolerable risk. It is essential that this analysis is undertaken by a competent person.

53. Examples of methods for assigning SILs to safety functions can be found in IEC 62061 (Annex A) and IEC 61508-5. When applying techniques such as these, it should be remembered that the acceptable probability of occurrence for a particular hazardous event is specific to the application. Determining the tolerable risk for a particular situation therefore requires many factors to be considered. It is only when this tolerable risk has been decided that the SIL required to adequately reduce the risk to this level can be determined.

54. A SIL is assigned to each safety function in a safety-related control system and has a strong influence on the requirements that have to be taken into account during the design and integration of a safety-related control system. These measures, together with the calculation of failure rates for the safety-related control systems, are an integral part of the process of achieving a safe design.

55. Central to IEC 62061 are the Safety-Related Electrical Control System (SRECS) and the Safety-Related Control Function (SRCF). These relate to the E/E/PE elements of a machine's safety-related control system and the control function to be performed by it.

56. A SRCF will be specified in terms of its particular role or function and the safety integrity associated with the performance of this function. Where a SRECS is used to implement one or more SRCFs, its hardware and software must achieve a SIL consistent with the highest safety integrity requirements of the individual SRCFs.

57. The SIL that can be claimed for a SRECS consisting of one or more subsystems will be constrained by the lowest SIL Claim Limit of any subsystem and by their combined probability of dangerous random hardware failure. The SIL Claim Limit of a SRECS

subsystem determines the maximum SIL that can be claimed in relation to its architectural constraints and its systematic safety integrity (extent to which systematic failure avoidance measures have been applied). For a SRCF to achieve a particular SIL, the SIL Claim Limit of each SRECS subsystem must therefore equal or exceed it, and their combined probability of dangerous random hardware failure must not exceed the target failure value for that SIL. The example of a SRECS design covered by Annex B of IEC 62061 illustrates this concept.

Comparing SILs and Categories

58. The fact that categories in EN 954-1 and SILs in IEC 62061 both share allocated numbers 1 to 3 does not mean that there is a direct relationship between them. Both standards are written from different perspectives and so SILs and Categories are not comparable measures. Categories are not to be assumed as hierarchical measures for all applications" with "a hierarchical measure across technologies, whereas SILs are hierarchical because they relate to probabilities of failure.

59. A safety-related control system comprised entirely of components meeting the requirements of EN 954-1 category 4 may reasonably be expected to meet the target failure value (probability of dangerous failure of the SRCF per hour) associated with SIL 3 . However, no assumption should be made about the target failure measure achieved by safety-related systems which include components to EN 954-1 categories B, 1, 2 or 3, because EN 954-1 has no quantified requirements on the likelihood of dangerous failure for these categories. Whereas the category of a safety-related control system relates chiefly to its structure, and therefore its hardware fault tolerance, its SIL is based on its probability of dangerous random hardware failure and the constraining effect of the maximum SIL Claim Limit (see para. 57).

60. For low complexity subsystems that have been designed in accordance with EN 954-1 and validated in accordance with ISO 13849-2 (effectively part 2 of EN 954), IEC 62061 provides a methodology for integrating them into a SRECS. The Category, Safe Failure Fraction[10] and Diagnostic Coverage[11] of the subsystem are used to derive a maximum SIL Claim Limit based on architectural constraints only, and a threshold value for probability of dangerous failure. Consideration of the systematic safety integrity aspects enables an overall maximum SIL Claim Limit to be determined.

61. This maximum SIL Claim Limit based on architectural constraints is a function of the category (hardware fault tolerance) and Safe Failure Fraction combination, whilst the threshold value for probability of dangerous failure is determined by the combination of category (hardware fault tolerance) and Diagnostic Coverage. Consideration of the systematic safety integrity aspects enables an overall maximum SIL Claim Limit to be determined, which in conjunction with the probability of dangerous failure indicates the SIL for a complete safety-related control system.

62. The Performance Levels used by ISO 13849-1, which are derived in part from EN 954-1 categories, will be more comparable with SILs, as they are both quantitative and hierarchical measures of performance.

Safety Functions and Detailed Requirements for Amusement Devices

[10] Fraction of the overall failure rate of a subsystem that does not result in a dangerous failure.
[11] Percentage decrease in the probability of dangerous hardware failures resulting from the operation of the automatic diagnostic tests.

Stop and associated functions

63. When necessary (as decided by the risk assessment) the safety-related control system should provide the facility for, safety stopping and emergency stopping of the amusement device. Operational stopping, for example for loading and unloading passengers, is implemented by the primary control system

64. Stop functions should have priority over related start functions.

65. Stop functions may be provided in separate systems or in a single system depending upon the risk.

Safety stop function[12]

66. This function is intended to avert actual or impending danger and may be activated either manually or automatically. It should stop the relevant parts of the amusement device so as to reduce the overall risk to an acceptable level as quickly as possible.

67. A safety stop function should override operational stop functions but not emergency stop functions.

68. After a safety stop has been initiated, a restart may not take place until the cause for the stop has been removed.

69. The relevant parts of the amusement device should reach standstill in the shortest time commensurate with avoiding hazardous conditions with due regard to all safety requirements including:

(a) general integrity of the machine and structure;

(b) safe accommodation of passengers; and

(c) decelerations.

Emergency stop function

70. Provision should be made, where indicated by the risk assessment, for a manually initiated emergency stop. The emergency stop should conform with the requirements of EN 418 and should function as either a stop category 0 or stop category 1 as defined in EN 60204 -1, depending upon the outcome of the risk assessment.

(a) A category 0 stop is caused by immediate removal of power

(b) A category 1 stop is a controlled stop with power available to the machine actuators to achieve the stop and then automatic removal of power when the stop is achieved.

71. Manual emergency stop actuators should be placed in positions that are easily accessed by appropriate operators, attendants, maintenance personnel, and in some circumstances passengers, who may need to stop the device for safety reasons.

72. Subject to risk assessment and operational considerations, the amusement device should reach standstill in the shortest time commensurate with avoiding hazardous conditions with regard to all safety requirements including:

(a) general integrity of the machine and structure;

[12] In some applications, a safety or emergency stop may result in such problems as difficult recovery of passengers and / or restart. If a stop could arrest the ride in other than the normal operating stop position, means should be provided, e.g. by fixed platform, so that the passengers may be disembarked safely

(b) safe accommodation of passengers; and

(c) decelerations.

73. After an emergency stop has been initiated, a restart may not take place until after the cause for the stop has been removed. An emergency stop may be over-ridden to allow the safe recovery of passengers by trained personnel who should follow a safe system of work, but this should not allow the ride to be operated in normal operational mode while the recovery operation is taking place

Other safety functions

74. Single mechanically-actuated sensing devices (e.g. limit switches) on interlocking and / or monitoring systems should be actuated in the positive mode or where this is not reasonably practicable be monitored so that any failure that may lead to danger is detected and acted upon to ensure safety as determined by risk assessment.

(a) Subject to risk assessment, unmonitored negative mode devices should not be used.

(b) The risk assessment may also determine that positive mode switches may still need to be monitored so that any failure that may lead to danger is detected

75. Where the risk assessment shows it to be necessary, interlocking and monitoring devices should be selected and positioned so that they are not easily or accidentally defeated or interfered with by persons riding in or on the amusement device.

76. In block zone systems any paired (providing redundancy) sensors should normally be configured so that:

(a) For entry to the block either one sets the block as occupied (OR in logic terms).

(b) For exit from the block both are required to reset the block to free (AND in logic terms).

77. The designer should specify, for inclusion in the Operations Manual, the limits of any adjustments and any necessary checks and / or tests needed to confirm the correct adjustment and operation of the interlocking and / or monitoring system.

Safety related parameters

General

78. Means should be provided to ensure that the values of the safety related parameters stay within predetermined levels defined by the risk assessment. A safety-related parameter is a variable which may be adjusted manually or as part of normal operation and which, if it moves outside predetermined boundaries, may lead to danger.

Speed

79. Speed is an important safety critical parameter for amusement devices where accelerations, and consequently forces, are dependent on the speed of amusement ride elements. Therefore, speed control can prevent hazardous effects on structures and passengers.

80. The following speeds should be considered.

(a) **Minimum operational speed:** The minimum speed necessary to ensure, for a stated operational condition, the safe containment of passengers and the intended function and the integrity of the amusement device.

(b) **Normal operational speeds:** Speeds at which the device will normally run and which will be between the minimum operational speed and the maximum operational speed. The speed may vary during the ride cycle.

(c) **Maximum operational speed:** The maximum speed at which, for a stated operational condition, the safe containment of passengers and the intended function and the integrity of the amusement device are ensured during repeated or sustained use.

(d) **Maximum achievable speed:** The maximum value of speed achievable by an amusement device element, without any restriction of control.

81. For a particular part of the ride cycle there may be different operating speeds. In particular, subject to the penultimate sentence of this paragraph and paragraph 54 below, the following safety functions should apply to prevent the amusement device operating outside the design parameters.

(a) The control system should control the speed between the minimum and maximum operational speeds for that part of the ride cycle.

(b) If the device either fails to achieve a minimum operational speed after a predetermined time, or the speed falls below the minimum operational speed, then the control system should perform a safety stop.

(c) If the speed of the device rises above the maximum operational speed, then the control system should perform a safety stop.

In some cases, risk assessment may show that one or more of these safety functions is not required. In others, it should be used to justify the safety category or safety integrity level.

82. The risk assessment should evaluate the effects on the structure and/or machine and passengers due to any achievable speeds.

83. If the maximum achievable speed is lower than or equal to the maximum operational speed, the control system does not require additional speed limiting circuits. But if the maximum achievable speed is greater than the maximum operational speed, taking into account foreseeable fault conditions, additional means may be necessary to ensure that the maximum operational speed is not exceeded. Also if the machine does not reach, or falls below, the minimum operational speed, additional means may be needed to ensure that the minimum operational speed is achieved or a safety stop is performed.

84. In some amusement devices (e.g. those in which a multiple passenger unit is made to swing and/or rotate about a horizontal axis) the instantaneous positions, speeds and accelerations may be very dependent upon the design of the control circuits. Full details of control, including feedback characteristics, need to be available for use in the stress analysis.

Passenger restraint device status and behaviour

85. Where a control system is involved in the operating, interlocking or monitoring of passenger restraint devices, its safety function and required safety integrity should be determined from the risk assessment.

86. Guidance on the principles for the design and selection of interlocking devices is published in EN 1088, and guidance on their incorporation into safety related control systems is also available in BS PD 5304. These two standards relate specifically to guarding of machinery. However they do contain some useful advice applicable to interlocking systems on amusement devices. Interlocking systems are not always necessary, appropriate, or practical to be installed on an amusement device.

87. The following guidelines should be taken into account. Any departures from these guidelines should be detailed and justified in the risk assessment.

(a) Positioning for starting

i. Closure and locking of restraints should be confirmed either by personnel or automatic systems before starting the ride cycle.

ii. This confirmation need not be automatic.

(b) Enabling of release

i. Control systems should not allow the release of the restraint devices unless it is safe to do so or unsafe not to do so.

(c) Alarms and warnings

i. Where an operator relies on audible alarms or visible indications as evidence that restraint devices are locked in the closed position, such alarms or indications should have the necessary safety integrity as indicated by the risk assessment in accordance with Chapters 1 and 10 of this Guidance.

(d) Loss of power supply should not:

i. allow the automatic release of restraint devices unless such release would not endanger the passengers or a suitable system of work is in use to ensure passenger safety.

ii. prevent the intentional release of restraint devices when required to ensure the safety of the passenger or for operational purposes, e.g. manual release.

(e) Monitoring of position

i. The need for the monitoring of the position of passenger restraint devices and their interlock latches should be determined by the risk assessment in compliance with Chapters 1 and 10 of this Guidance.

Inhibiting or bypassing of safety functions

88. The inhibiting or bypassing of safety functions should not result in any person being exposed to hazardous situations. When safety functions are inhibited or bypassed, safe conditions should be provided by other means. Removal of inhibits or bypasses should result in all safety functions of the safety-related parts of the control system being automatically reinstated.

89. If it is necessary to manually suspend safety functions, e.g. for set up, adjustments, maintenance, and repair, the following criteria should be applied:

(a) reinstatement of the safety functions of the safety-related parts of the control system before normal operations can be continued;

(b) effective and secure means to prevent manual suspension in those operating modes where it is not allowed;

(c) depending upon the risk assessment, consideration should also be given to the provision of a mode selection device or means capable of being secured (e.g. locked) in the desired mode so as to prevent automatic operation. In addition, consideration may need to be given to the provision of one or more of the following:

i. initiation of motion by a hold – to - run device or by a similar control device;

ii. a portable control station (e.g. pendant) with an emergency stop device and, where appropriate, an enabling device. Where a portable station is in use, motion may be initiated only from that station;

iii. limitation of the speed or the power of motion.

Control modes

90. Control systems should have one or more control modes relevant for their application. Control modes can be divided into:

(a) pre-operating modes (without passengers) such as for setting, adjustment, programming, testing, cleaning, maintenance, trouble shooting and repair;

(b) operating modes such as manual, semi-automatic and automatic cycle, for operation with passengers. There may be variations and combinations of operating cycles;

(c) non operating modes where the pre-operating or normal operating mode is not possible due to abnormal circumstances.

Change of control mode

91. A change of control mode should not cause a hazardous condition. It may be necessary to:

(a) bring the ride to a stop, requiring an operator start command to restart the ride, following a change of control mode;

(b) prevent inadvertent change of control mode, including unexpected start-up; or

(c) bring a change of control mode to the attention of the operator.

92. The following requirements should also be adopted where necessary:

(a) the appropriate mode selector should be so located that it can be operated safely;

(b) when a hazardous condition can result from a mode selection, such selection should be prevented by suitable means (e.g. key operated switch, access code);

(c) mode selection by itself should not lead to initiation of motion of any passenger unit – a separate action should be required;

(d) safeguarding should remain effective for all operating modes;

(e) indication of the selected operating mode should be provided (e.g. the position of a mode selector, the provision of an indicating light, a visual display indication).

Pre-operating mode

93. When in pre-operating mode the amusement device should operate only by a

separate action of the operator. The following conditions should be met:

(a) An authorised person should be in overall control.

(b) Depending on the risk assessment, the control of more than one subsystem which could cause a hazard should either be prevented by the safety-related control system or be under the sole control of a single operator.

(c) Depending on the risk assessment, safety functions should either continue to operate or be under the sole control of a single operator.

(d) All system emergency stops should remain effective.

Operating modes

94. There may be more than one operating mode. The amusement device should operate only after an initiation by the operator or under his supervision.

95. These modes are the only control modes which are allowed for normal operation with passengers, and all the safety functions should be in use.

96. In general, operating modes can include:

(a) manual, if all operating cycles are under the control of the operator;

(b) semi-automatic, if part of the operating cycle is controlled by means of one or more automatic program;

(c) automatic, if all operating cycles are controlled by means of one or more automatic program.

97. In operating modes, the following requirements should be met;

(a) The cycle should be initiated by the operator apart from special cases, such as continuous loading and unloading, and providing the risk assessment allows it;

(b) Means should be provided if necessary to prevent the ride time exceeding a predetermined value based on passenger discomfort;

(c) The selection of other operating modes or programs should not cause a hazard;

(d) During passenger loading or unloading mode, when the ride is at rest, it should not be possible for the ride to start, or move inadvertently, unless the operator has signalled the control system to do so. The required safety integrity level of this safety function should be determined from the risk assessment.

(e) Amusement devices in which loading and unloading occur without the device coming to a stop should be provided with a built-in device or procedures to ensure that the operator maintains his supervision of the ride. The speed of the device during loading and unloading should be treated as a safety-related parameter.

Non-operating mode

98. The amusement device, either whole or in part, is considered to be in a non-operating mode if, for example, any of the following occurs:

(a) Loss of power

(b) Restoration of power

(c) Actuation of an emergency stop

(d) Initiation of a safety stop

99. The safety related control system should ensure that:

(a) at any point in time, the state of the amusement device in non operational conditions does not lead to a hazard; and

(b) any safety critical parameters and data in the control system (preset or otherwise) should be maintained even during the course of operation resulting from safety or emergency stop or an equivalent event. If this is not possible, alternative means should be specified in order to ensure safety.

100. During the slowing and the stopping of the ride:

(a) a safe sequence of events should be followed; and

(b) the constraints set by the minimum operational speed and/or deceleration forces, applicable at the time, should be complied with.

101. Where loss of power could result in a dangerous condition, a reserve of energy should be available to provide the power necessary to enable the ride to be brought to rest and remain at rest, or other means should be provided to ensure safety.

102. Any reinstatement of power after a power loss should not automatically restart the ride without a command by the operator.

103. In the non-operational mode the following conditions should be met in addition to those required for the pre-operating mode:

(a) Operations, whose combination could simulate the operating mode or could lead to hazardous conditions, should be allowed only in confirmed discrete steps by the safety-related control system. Suitable means should be provided to ensure that each separate operation is deliberately actuated.

(b) Notwithstanding a) above safety functions should remain effective in those operations where, if overridden, a more hazardous condition could occur.

(c) If the only way to recover passengers is to use the built-in override of a safety function, this special procedure should be performed by an authorized operator and be visually monitored either by that operator or by a subordinate in good communication with him.

Collision prevention by control systems

104. Where required by a risk assessment a means of preventing unintentional collisions should be provided. An example of such means, a block-zone system, is provided.

Block-zone control system

A block-zone control system consists of the partial or complete subdivision of the ride circuit into sections, called block-zones, each of which should not be occupied by more than one passenger unit or train at the same time, except as allowed below.

The number of block-zones into which the ride circuit is subdivided should be sufficient to prevent unsafe collisions. In some devices dependent on the risk assessment more than one passenger unit may be allowed into, or to overlap into, one or more of the block-zones with safety being assured by other means. For example, speed may be restricted and / or buffering may be provided to allow passenger units to come into contact with each other at station areas or immediately before a lift in a log flume.

A block-zone control system normally includes the following elements:

- a means of signalling the occupied status of a block-zone e.g. occupancy sensors;
- a means of signalling the clear status of a block-zone (clearance sensors);
- control logic;
- devices which can stop the passenger unit when necessary within the required distance to prevent collisions (e.g. stopping devices).

Subject to risk assessment, the control system should perform a safety stop in the case of equipment failure which could lead to an increase in the risk to passengers; e.g. the failure of one out of a set of redundant sensors, or loss of power. The risk assessment should determine whether it is safer to allow unaffected passenger units, such as those ahead of a failed sensor, to carry onwards to a suitable disembarkation point, or even the normal disembarkation point.

On restoration of power (including electrical, hydraulic or pneumatic), if there is no automatic system to ensure the safe restart of block-zone operation, the system should prevent the opening of brakes or the initiation of movement except under a manual system of work. If an automatic restart is provided, it should be initiated manually.

In any block-zone, clearance sensors should be so located that if the passenger unit stops for any reason as soon as it leaves the block-zone, the following unit should be prevented from colliding with it even if stopped in the most unfavourable condition possible.

Sensors should be so located and / or control logic designed such that a block-zone is recognised as occupied before the previous block-zone is cleared.

Requirements for stopping devices

105. All brake or stopping systems should conform to the following requirements:

(a) The total required number of stopping units within a group should be determined by risk assessment.

(b) For a group of redundant brakes or stopping units, loss of power from or component failure of any brake or stopping unit, or a defined number of units as decided by the risk assessment, should not reduce the ability of the remaining stopping units within the group to bring a passenger unit to a safe halt.

(c) Stopping devices should be located so that, after a stop, the passenger unit, in normal conditions, can be restarted safely.

(d) The brake system should operate, when demanded to do so for safety reasons, within a time that will enable a ride to be brought to a halt within the required distance, no matter what the environmental or operational conditions.

(e) The control of final actuating systems of stopping devices (whether electrical, electronic, mechanical, pneumatic or hydraulic) should either:

i. cause the passenger carrying device to stop within safe limits in their de-energised state; or

ii. if any elements are energised to cause the stop, then an adequate level of safety should be provided by means such as redundancy and/or diversity.

106. Powered lifting or shifting devices may be used as stopping devices under the following conditions:

(a) The device should have the ability positively to halt the passenger unit or train in such a position that it is not possible for any external influence such as environmental conditions or change in load to cause it to continue.

(b) The device should be de-energised by suitable means, such as contactors, and the passenger unit or train effectively should be prevented from reversing in a dangerous manner by an anti-rollback device.

(c) An electronic device may be used to bring any device or motor speed to zero. However, if the speed does not reduce to zero within a safe distance, or if the electronic device restarts, then the supply to the final actuator or motor should be physically interrupted, e.g. by means of contactors, or other diverse means.

(d) The device, as well as any control circuits, whether electrical, electronic, pneumatic or hydraulic, should either:

i. cause the passenger carrying device to stop within safe limits in de-energised states, or

ii. if any elements are energised to cause the stop, then an adequate level of safety should be provided by means such as redundancy and/or diversity.

107. When a device is used to trim the speed of the passenger unit or train and also as a stopping device and if the trimming or stopping function has safety implications, then the sensors, control logic and the devices should be considered as part of the safety-related system and treated accordingly. In cases where trimming has no safety implications this part of the control system need not be safety-related.

Relevant Standards & Other Publications

EN 418	*Safety of machinery: Emergency Stop Equipment.*
EN 954-1	*Safety of machinery – Safety Related Parts of Control Systems Part 1: General Principles of Design*
ISO 13849-2	Safety of machinery – Safety-related parts of control systems – Part 2: Validation
PD CR 954-100	*Safety of machinery – Safety-related parts of control systems – Part 100: Guide on the use and application of EN 954-1:1996*
EN 1050	*Safety of machinery – Principles of Risk Assessment.*
EN 1088	*Safety of machinery – Interlocking devices associated with guards. Principles for design and selection*
PD 5304	*Safe use of machinery.*
EN 60204-1	*Safety of machinery – Electrical equipment of machines. Specification for general requirements*
IEC 61508	*Functional safety of electrical / electronic / programmable electronic safety-related systems*
IEC 62061	*Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

Chapter 10

Passenger Units and Containment

General principles

1. The passenger units[13] should be designed to contain safely all passengers for whom the Operations Manual states that the ride is suitable. To achieve this the designer needs to specify the target population for the ride, e.g. maximum and minimum size / weight and other physical limitations.

2. The sizing criteria for passengers should be such that they can be measured and distinguished easily by the ride attendants with minimal or no ambiguity.

3. The designer needs to provide secure and safe accommodation for passengers at all stages during the ride cycle and foreseeable emergency situations e.g. the application of emergency brakes.

4. Safe and secure accommodation includes minimising the risk of injury from the following causes:

   (a) physical injury within the confines of the passenger unit

   (b) injury due to forces that result in adjacent passengers being pushed together

   (c) moving[14] into a position of danger, i.e. from where there is an unacceptable risk of passengers falling or being injured by contact with static or moving parts

   (d) injury on boarding or leaving ejection

   (e) injury from powered restraints

5. Some of the potential risks are discussed in the following paragraphs.

Passenger Accelerations

6. The accelerations and higher derivatives of velocity experienced by the target passenger range needs to be calculated by the designer and subsequently confirmed by measurement. Bearing in mind that there can be significant variations from passenger to passenger (e.g. according to position in a roller coaster train), it may be necessary to carry out these calculations and measurements for head, stomach and foot positions for each passenger, in each seat, of each car.

7. The variations of acceleration over the ride cycle should be such that they do not cause significant nausea, skeletal injury, etc.

Safety Envelopes

8. The design should specify the "safety envelopes" for the ride i.e. the minimum spaces around the moving parts necessary to prevent any part of a passenger or spectator from coming into contact with anything that could cause injury. This could be a moving part

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[13] Passenger unit - Any car, carriage or other fixture, on which a person sits, stands, etc., being part of an amusement device.
[14] Whilst the above is intended primarily to deal with involuntary or unintentional movement, risk assessment may demonstrate the need for measures to control foreseeable, intentional movement.

of the ride or a stationary part which is too close to a moving part, e.g. barriers and items of themeing. The most important envelope to consider is that around the path of the passenger units.

9. The dimensions of safety envelopes should be based on anthropometric data, taking into account the style of containment. An example demonstrating changes in reach distances in relation to containment is given below. Where appropriate, the envelopes should be based on dynamic rather than static measurements since passengers or spectators may try to reach towards places of danger.

10. The type of object that is likely to be collided with may also alter the risk, as for example an extended hand or finger coming into contact with a soft or rounded structure might present a lower level of hazard than the same extremities colliding with a sharp or square object. The collision speed will also be a factor in determining the risk of injury.

11. Whenever design situations involve a real risk of injury and depending on the findings of a risk assessment, the extreme percentile dimensions indicated by anthropometric data may be used to calculate safe clearance envelopes.

12. Additional safety tolerances may also need to be added to the bare reach distances to ensure absolute clearance.

13. As examples of extreme percentiles (99.99th %iles) that might be used given the risk of an irreversible injury, and with no mitigating control measures the following anthropometric data may be useful.[15] These measurements do not contain any added safety tolerances as suggested in paragraph 10 above.

(a) Overhead fingertip reach – sitting (from base of seat to highest reach point)

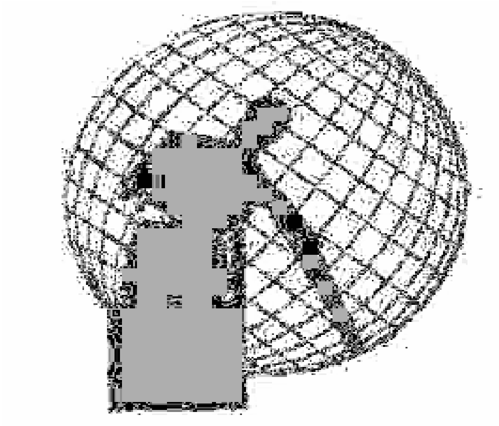
i. 99.99th %ile 1626 mm

(b) Sideways fingertip reach – Shoulder[16] (acromion) to furthest reach point sideways

i. 99.99th %ile 930 mm[17]

	Unrestrained upper body, **raised seat side**. Reach envelope for adult leaning over Example as used in para. 11(b) page 72

[15] US adults 18 to 64 – PeopleSize 2000 - Open Ergonomics Ltd.
[16] Due to scarcity of relevant anthropometric data the measurement given here is from the acromion (the bony tip of the shoulder) rather than the underarm.
[17] This measurement assumes no unrestrained ability to reach further out due to low seat sides.



Unrestrained upper body, **low seat side**.
Reach envelope for adult leaning over

Examples of dynamic anthropometry reach envelopes given differing seat arrangements
(These examples are not to scale)

Counterweighted Passenger Units

14. Where parts of the moving structure have counterweights to balance the passenger units, the designer should make sure that the passenger unit cannot move under the action of the counterweight unless it is safe to do so. This is likely to involve provision of suitable parking brakes and may involve interlocking.

Passenger Containment

15. The containment system shall be designed around the target passenger population. The designer shall consider how the following factors could affect passenger safety:

(a) **static factors** - the relationship between the dimensions of the passenger and the dimensions of the containment system

(b) **dynamic factors** - the relationship between the forces imposed on the passenger by the ride motion and the voluntary and involuntary responses of the passengers to those forces

(c) **psychological factors** - the passengers' likely perceptions of the ride and responses to it. As well as normal use, passenger behaviour which could reasonably be expected should also be considered[18]

16. In specifying the form of the containment the designer needs to :

(a) determine the size and direction of forces which will be exerted by elements of containment on the passengers (and vice versa)

(b) assess the risks arising from the forces

(c) identify the parts of the passengers' bodies which require support for each

[18] The following footnote is based on an extract taken from *Community legislation on machinery – Comments on Directive 98/37/EC; 1999 Ed: European Commission*
The designer is required to foresee only "reasonable" situations, i.e. based on logic, rational usage, and common sense. In any event, the concept of "reasonably foreseeable" precludes the irrational (e.g. drying the cat in the microwave). The foreseeability of the danger includes evaluating the complexity and plausibility of the combination of circumstances which would need to occur for the potential of harm to be realised. Consideration will need to be given to foreseeable situations in which the passenger's expected actions, as a result of not being able to fully perceive the danger, may expose him to an increased risk

anticipated force

(d) using body size data appropriate to the target population[19], identify the maximum and minimum dimensions of the containment system necessary to contain passengers safely.

(e) lay out the design so as to contain safely all passengers who will be permitted by the Operations Manual to use the ride.

17. Any component that plays a role in directly protecting a riding passenger from the hazards identified in paragraph 3 (above) shall be considered part of the containment system. The following examples should be taken into account along with any others that might present a hazard:

(a) Loads resulting from passengers bracing themselves when designing passenger restraints and other parts of the containment (e. g. footrests), railings and bracing devices within the passenger unit.

(b) The potential for injury due to inertial forces that result in adjacent passengers being forced together. This could be particularly likely in the case of rotating equipment and exacerbated by inappropriate (i.e. low friction) seat materials

(c) All significant situations during the ride cycle including loading, unloading and emergency situations. The magnitudes of maximum bracing forces are dependent upon the detailed design of the containment.

18. All passengers within the size limits specified in the Operations Manual shall be able to reach comfortably all parts of the containment system necessary for their safety. Typical parts and their requirements are :

(a) **seating** - shall be based on ergonomic criteria and provide support for all body parts susceptible to injury

(b) **footwells** - shall permit all passengers to brace themselves using their feet where the risk assessment shows this to be necessary

(c) **grab-rails** -shall be suitably designed and positioned for use by the target population. Where a risk assessment shows that there is a foreseeable risk of injury caused by contact with the grab-rail (e.g. during an emergency stop), the designer should consider the need for re-design, padding or restraints

(d) **head rests or head restraints** - appropriate to the ride motion should be included in the design where there is a foreseeable risk of whiplash injury

(e) **restraint systems** - shall be designed as an integral part of the containment system.

19. Where passengers ride in a sitting position, the seat is one of the most important parts of the containment system. Besides considering the size and shape of the seat, the designer should consider carefully the materials to be used for the surface.

(a) Hard materials, e.g. fibreglass, wear well but offer little comfort or protection to the passenger. Also they often have a smooth surface which provides minimal friction between the passenger and the seat. This can allow passengers to slide on the seat as the unit changes direction.

[19] Tables 10.1 to 10.3 indicate some of the important dimensions. Published anthropometric data for children is based on age, while it is normal to restrict use of amusement rides on the basis of passenger height. British data converted to a height basis is given in Table 10.4

(b) Hard finishes should only be specified if they do not put passengers at significant additional risk. If they are specified, the designer may need to consider techniques for reducing the likelihood of passengers sliding.

20. On rides carrying standing passengers the designer should take account of how the passengers are to be contained e.g.:

(a) standing and restrained

(b) standing and unrestrained

(c) held in place by ride forces

21. Depending on the containment requirements for standing passengers, the designer may need to take account of:

(a) the positions of passengers' centres of gravity

(b) the forces they are subjected to and the reaction forces they are expected to exert

(c) their gripping reach.

22. Where the risk assessment shows it to be necessary, the containment should be designed to prevent ejection and to prevent passengers from being able to move bodily about on the device except where it is stationary or where there is a clear intention for the passengers to move. Under such conditions the design should ensure that risk of injury is low and ample bracing and handholds should be provided.

23. The designer should ensure that he provides adequate information about the height (or other) limits on which the risk assessment and the design of the containment system are based. This will need to be included in the Operations Manual supplied with the ride.

Structure of passenger units

24. The design should specify how the passenger units will be secured to the main part of the device and demonstrate that the attachment will be strong enough to withstand the forces and moments which will be imposed. Where the risk assessment has identified the need for a secondary means of holding the unit if the main attachment fails, it is necessary to demonstrate that this secondary attachment is capable of withstanding the loadings (including "snatch" loadings) which may result from the failure of the main attachment.

25. Every passenger unit should be strong enough to withstand the forces imposed. It is normally reasonably pessimistic to ignore plastic or composite materials and base structural design calculations on the underlying steel framework. However, the localised strength of such shells may still need to be assessed.

26. All equipment involved in passenger containment, including bars, belts, harnesses, handholds, footrests, locks, catches, hinges and other attachment points should be of good construction and adequate strength to withstand the forces likely to be placed upon them by passengers (for example when bracing themselves) as well as by the ride forces.

27. All parts of the containment system should be free from sharp edges, projections and obstructions. Fixtures and fittings should not cause injury e.g. armrests should be smooth and continuous with the rest of the seat wherever possible.

28. Appropriate padding should be used on any part of the containment system against which the passenger may be forced by the motion of the ride to the extent that is necessary to adequately control the risk. This particularly needs to be assessed in relation to fittings

which may also benefit from careful positioning and adjustment.

29. Materials which will not become dangerous in use, e.g. through splintering, are preferred for passenger units. This is particularly important on slides where the whole running surface forms the passenger unit. The alternative is expensive inspection and maintenance programmes which the designer should specify.

30. Any running gear (e.g. wheels, rollers etc.) should be designed to absorb all forces likely to lead to derailment or lift-off. Devices to prevent lift-off should be designed to support loads equal to at least 50% of the fully loaded unit unless calculations indicate that greater forces or fatigue may be involved.

Passenger restraints

31. Normally the following principles will apply to the provision of passenger restraints on new rides.

(a) Where the risk assessment indicates that a restraint is required, it should be of appropriate design and construction (see Figure 10.2), with safety critical components accessible for maintenance.

(b) Where the risk assessment indicates that a restraint is required, there should be confirmation of safe closure, by personnel and / or by automatic systems.

(c) Where the risk assessment shows it to be necessary, the release should not be operable by the passengers unless the ride is in a suitable state for disembarkation. (This permits those catches which can be opened by passengers only when the unit is stopped in the unloading position)

i. The principle in the above may be achieved by releases which are shrouded, out of reach, or remote (e.g. electrical).

(d) The risk assessment should decide whether the restraint should be designed to be fail-safe open (or openable) or fail-safe locked. (For example, it is generally thought better, because of fire risk, for restraints to fail open, or openable, in the case of Ghost Train types in enclosed structures).

Restraint Construction

32. Some of the design / construction implications of the above may be :

(a) springs which have not been designed with infinite fatigue life;

(b) wear of latches and plungers;

(c) fatigue of restraint bars and other structural and mechanical components, for instance in the locking mechanism;

(d) short circuits and cross-talk in control systems.

Where there is a significant risk associated with these considerations the designer may be able to ensure safety by specifying an appropriate inspection and maintenance schedule consistent with the fatigue or wear lives of the components.

33. It is normally possible to estimate by measurement the maximum bracing forces which may be imposed on a restraint by the passengers and dynamic loadings will also be calculable. However, there is normally an absence of data on actual restraint force variations in service (needed for the assessment of fatigue). In this case it will be necessary for the

designer to:

(a) carry out testing to establish appropriate design loads; or

(b) otherwise justify design loads; or

(c) issue written guidance on the safe monitoring / inspection of relevant restraint components.

34. Anchor devices for seat belts and harnesses and the structures to which they attach should be designed to cater for the static and dynamic loads which will be imposed.

Restraint Closure/ Locking / Release

35. If human confirmation that a restraint is properly closed and secured is to be relied upon for safety then this should be clearly stated in the operating manual. The provision of appropriate training for attendants should also be recommended. It should not be forgotten that there may be some advantages to manual (rather than solely automatic) checking of closure. For instance, the attendant is effectively carrying out a functional test of the restraint every time a passenger rides.

36. It is important to assess whether an automatic system for checking restraint closure can provide a satisfactory level of confirmation and reliability. For manual checking, the designer should consider the ergonomics of the system to ensure that safe closure and locking can be confirmed readily by the attendant / operator.

37. If it is possible for a ride to operate with the restraints in unoccupied passenger units still open, then it must be confirmed that this does not present any hazard (e.g. protruding parts/ejected components) and that the device will not suffer damage in this configuration (e.g. due to higher than expected loads on unrestrained components)

38. A release should require a definite action by an operator or attendant to open it or if automatic operation is used, be interlocked with the ride control system, so that it opens only when it is safe for passengers to alight (e.g. in the station).

Other Restraint Design Issues

39. Restraints should be designed to be easily fitted to the passenger, comfortable in use and not likely to cause injury in normal operation or emergencies. Where a hazard may arise from ejection or movement of the passengers, the restraint should be capable of adjustment to suit each passenger, or there should be further individual adjustment devices provided on the restraint. Where it is designed to fit more than one passenger it should be able to safely contain any combination of passengers who are within the permitted size range.

40. Power operated restraints should not act with excessive force on any sensitive or fragile part of the body - forces exceeding 0.15 kN at the point of restraint application are normally undesirable. The restraint should retract in response to an obstruction before there is sufficient force to cause injury.

41. Powered restraints should not be used where there is a risk to passengers from fire unless another suitable means of escape is provided. There should be a means of opening in emergency e.g. power failure.

42. Restraint catches and locking devices should be designed not to work loose (e.g. as a result of vibration or the forces imposed by the ride) where a significant risk would result.

43. Seat belts or harnesses should

(a) if adjustable, have self-locking adjustments

(b) prevent passengers approaching a place of danger where a risk assessment shows this to be necessary

44. Guidance on the technical basis of conventional vehicle seat belt specifications may be found in Annex I of the European Directive 2000131EC and, for children, in UN-ECE Regulation 44.03

45. There may sometimes be more than one independent restraint (e.g. lap bar plus over- shoulder restraint). In such circumstances there may be a safety advantage in designing independent release mechanisms (and control systems) for the different restraints.

46. For rides on which there is a risk of the passenger unit stalling (e.g. with the passenger units steeply banked or even upside down), the restraints should be designed to prevent them falling. Alternatively, they may be fully enclosed in a cage. In this case, any restraint should protect them from normally coming in contact with the walls of the cage if this could lead to injury.

47. Designers should specify appropriate operation, inspection and maintenance instructions.

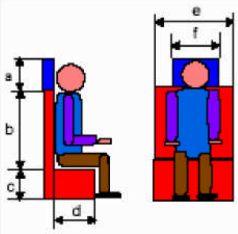
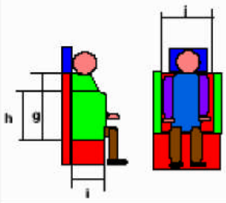
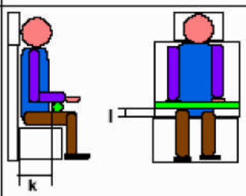
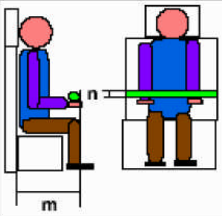
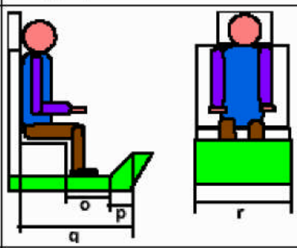
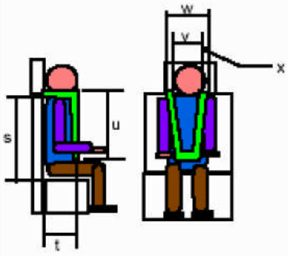
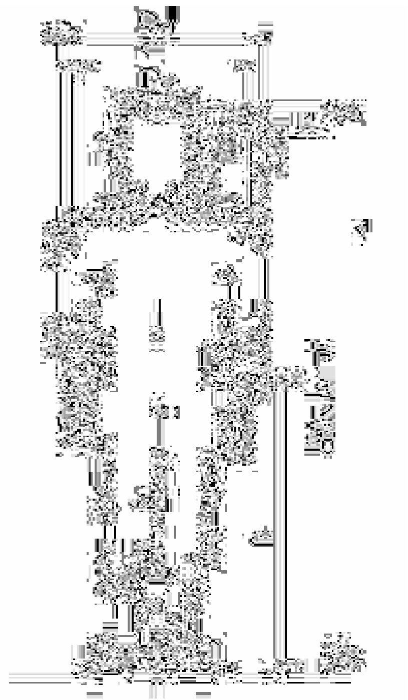
Table 10.1 Containment system components.			
Component			**Description**
Seating		a	head rest height
		b	seat back height
		c	seat pan height
		d	seat pan depth
		e	seat back width
		f	head rest width
		g	high side support height
		h	low side support height
		i	side support depth
		j	distance between side supports (per passenger)
Lap bar		k	distance from seat back to rear edge of lap bar
		l	distance from seat pan to lower edge of lap bar
Handrail		m	distance from seat back to front edge of handrail
		n	diameter of handrail
Footwell		o	length of horizontal floor from seat to front of car
		p	footrest length
		q	distance from back of seat to front edge of footrest
		r	footwell width (per passenger)
Over Shoulder		s	distance from seat pan to bottom edge of shoulder supports
		t	distance from seat back to back of trunk support
		u	trunk support overall length
		v	distance between inside edges of shoulder supports
		w	distance between outside edges of shoulder supports
		x	shoulder support width

Table 10.2 - Body dimensions and suggested ranges

Measurement	Body dimension	Adjustable or not	Percentile range
a	Shoulder to crown	x	95th
b	Sitting shoulder height	x	95th
c	Popliteal height	x	5th
d	Buttock popliteal length	x	5th
e	Bi-deltoid	x	95th
f	Head width	x	95th
g	Sitting shoulder height (deltoid)	x	95th
h	g/2	x	95th
i	Buttock - popliteal	x	95th
j	Shoulder breadth (bi-deltoid)	x	95th
k	Abdominal depth	√	5th - 95th
l	Thigh clearance	√	5th - 95th
m	Forward reach	√ (x)	5th - 95th (50th)
n	Grip diameter	x	5th
o	Knee height	√	5th - 95th
p	Foot length, Heel ball length	x	95th
q	Hip height	x	95th
r	Foot breadth, hip breadth	x	95th
s	Sitting shoulder height	□(x)	5th - 95th
t	Chest depth	□	5th - 95th
u	Sitting shoulder height - thigh clearance	□(x)	5th
v	Head breadth	x	95th
w	Interacromion	x	50th
x	Shoulder length (to acromion)	x	95th

Table 10.3 Body Dimensions	
Measurement	**Body Dimensions**
a	Shoulder - crown
b	Sitting shoulder height
c	Popliteal height
d	Buttock - popliteal length
e	Shoulder breadth (bi-deltoid)
f	Head width
g	Sitting shoulder height (deltoid)
h	g/2
i	Buttock - popliteal length
j	Shoulder breadth (bi-deltoid)
k	Abdominal depth
l	Thigh clearance
m	Forward reach
n	Grip diameter
o	Knee height
p	Foot length, Heel ball length
q	Hip height
r	Foot breadth, hip breadth
s	Sitting shoulder height
t	Chest depth
u = b - l	Sitting shoulder height-Thigh clearance
v	Head width
w	Interacromion
x	Shoulder length (to acromion)
y	Thigh to toe length



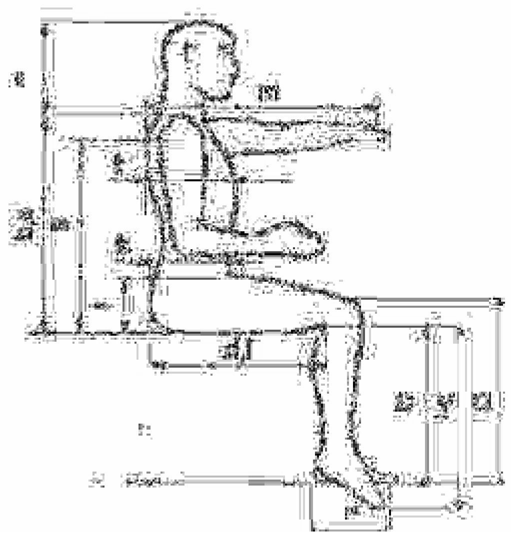


Table 10.4 - Body dimensions' associated with heights		Figures are 5th / 50th / 95th percentiles for British adults and children				
Measurement	Body dimension	Adult male	Height 1400	Height 1300	Height 1200	Height 1100
a	Shoulder to crown	265 / 315 / 365	242 / 262 / 282	237 / 256 / 275	235 / 252 / 269	225 / 240 / 255
b	Sitting shoulder height	540 / 595 / 650	435 / 460 / 495	400 / 430 / 460	375 / 400 / 425	350 / 375 / 400
c	Popliteal height	390 / 440 / 490	335 / 361 / 390	305 / 333 / 360	280 / 305 / 330	250 / 272 / 295
d	Buttock popliteal length	440 / 495 / 550	355 / 385 / 410	320 / 350 / 380	290 / 315 / 340	260 / 282 / 305
e	Bi-deltoid	420 / 465 / 510	290 / 335 / 380	280 / 325 / 370	250 / 288 / 325	240 / 273 / 305
f	Head width	145/155/165	132/146/160	130/145/160	123/123/123	123/123/123
g	Sitting shoulder height (deltoid)	540 / 595 / 650	435 / 460 / 495	400 / 430 / 460	375 / 400 / 425	350 / 375 / 400
h	g/2	270 / 298 / 325	212 / 230 / 248	200 / 215 / 230	187 / 200 / 213	175 / 187 / 200
i	Buttock - popliteal	440 / 495 / 550	355 / 385 / 410	320 / 350 / 380	290 / 315 / 340	260 / 282 / 305
j	Shoulder breadth (bi-deltoid)	420 / 465 / 510	290 / 335 / 380	280 / 325 / 370	250 / 288 / 325	240 / 273 / 305
k	Abdominal depth	220 / 270 / 320	145 / 185 / 220	135/175/215	135 / 160 / 185	135 / 155 / 175
l	Thigh clearance	135 / 160 / 185	95/117/140	90/113/135	75/ 95/120	72/ 93/114
m	Forward reach	835 / 890 / 945	545 / 580 / 620	500 / 540 / 580	475 / 508 / 540	435 / 470 / 505
n	Grip diameter	45/ 52 / 59	38/44/50	35/ 41 / 47	33/ 39 / 45	31 / 37 / 43
o	Knee height	495 / 545 / 595	415 / 445 / 475	380 / 410 / 440	345 / 370 / 395	305 / 330 / 355
p	Foot length, Heel ball length	240 / 265 / 290 170/190/210	194 / 218 / 242 151/168/184	185 / 210 / 235 145/160/175	165/187/210 140/155/170	155 / 173 / 190 130/148/165
q	Hip height	840 / 920 / 1000	690 / 740 / 790	630 / 680 / 730	565 / 613 / 660	500 / 540 / 580
r	Foot breadth, Hip breadth	85/ 95/105 310 / 360 / 410	77/86/95 210 / 255 / 300	75/ 85/ 95 200 / 245 / 290	65/ 75/ 85 185 / 217 / 250	62 / 70/ 78 180 / 207 / 235
s	Sitting shoulder height	540 / 595 / 650	435 / 460 / 495	400 / 430 / 460	375 / 400 / 425	350 / 375 / 400
t	Chest depth	215/250/285	125/165/200	115/155/195	110/140/170	110/135/160
u = b - l	Sitting shoulder ht. - thigh clearance	385 / 435 / 485	313 / 346 / 380	285 / 318 / 350	275 / 305 / 335	255 / 282 / 310
v	Head breadth	145/155/165	132/146/160	130/145/160	130/140/150	130/140/150
w	Interacromion	365 / 400 / 435	270 / 303 / 335	265 / 297 / 330	235 / 265 / 295	220 / 247 / 275
x	Shoulder length (to acromion)	145 / 170 / 195	127 / 150 / 174	120 / 145 / 170	115/140/165	110/133/155
y	Thigh to toe length	-/-/740	-/-/575	-/-/530	-/-/490	-/-/440

Grip diameter figures in row "n" and thigh to toe length in row "y" have been estimated only from data for adult males. Otherwise the Table values have been calculated from the age groups having average height nearest to the height to which the column relates. For methods used see 'Regression" and "Combination dimensions" on pages 60 and 61 in the Appendix of BSI PP7310.

Dimensions in mm, sources BSI PP7310 and "PeopleSize software, Open Ergonomics Ltd 1994-9". For example, the 5th percentile popliteal height associated with a height limit of 1200 mm would be 280 mm.

Relevant Standards and other Publications

European Directive 2003/3/EC	*Adapting to technical progress Council Directive 77/541/EEC relating to safety belts and restraint systems of motor vehicles.*
UN-ECE Regulation 44.03	*Uniform Provisions concerning the Approval of Restraining Devices for Child Occupants of Power-Driven Vehicles ("Child Restraint System")*
PeopleSize	*Software, Open Ergonomics Ltd 1994-9*
BSI PP7317, 1987	*ISBN0 580 15391 6*
Adult data	*The handbook of adult anthropometric and strength measurements - Department of Trade and Industry, Government Consumer Safety Research, 1998*
Child data	*The handbook of child measurements and capabilities - Department of Trade and Industry, Government Consumer Safety Research, 1995*

Chapter 11
Physical guards, barriers, fencing etc.

1. The design should specify the protection required from all dangerous parts of machinery, including transmission machinery. Further information is given in PD 5304, ISO 12100, EN 294, EN 349, EN 811, EN 953 and in the guidance to the Provision and Use of Work Equipment Regulations 1998 (abbreviated to PUWER).

2. Safeguarding of electrical equipment should comply with the Electricity at Work Regulations 1989, the Electrical Equipment (Safety) Regulations 1994 and relevant guidance. Workplaces should comply with the Workplace (Health, Safety and Welfare) Regulations 1992.

3. Where danger may occur from direct contact with live electrical parts the requirements of EN 60204 -1: 1998 paragraph 6.2 should be met.

4. Where a hazard exists, mechanical transmission machinery should be enclosed within guards or provided with other suitable means of preventing access while it is in motion.

5. A risk assessment should be made where the dimensions or arrangements of stairs, handrails, landings, ramps, or platforms cannot conform to relevant British or International Standards ref 5395. Slip-resistant surfaces should be considered, particularly for any parts which could become wet in use.[20]

6. Guidance on some aspects of barrier design, whether to protect against falls from height or against access to dangerous parts, is given in BS 6180. Although this relates to barriers in and about buildings, some of the advice may be useful for amusement devices.

7. Barriers, fencing or other measures needed to prevent access to dangerous parts should be specified where people may risk injury. Particular attention should be given to places where people could penetrate the safety envelope around moving parts of the device. Minimum barrier heights should be based on Table 11.1.

8. The design of stand alone fences round such rides as grass cutter Twist, Octopus, Big Wheel, should require the fence to be positioned so that, if it falls due to crowd pressure, persons will not fall into danger.

9. Every platform from which a person is liable to fall more than 600mm should be protected by a barrier (except at places where access is provided). The barrier should be at least 1000 mm high, securely fixed and provided with enough infilling to prevent people being trapped or falling underneath.

10. The design should provide for the safe evacuation of passengers including any stranded at remote positions. Barriers etc. on evacuation routes should comply with the preceding paragraphs and should be designed to meet the strength requirements in an appropriate category in Table 3.1.

[20] For further information see Chapter 1 – Risk Assessment and Appendix 1

Table 11.1								
Height above ground of the danger source, a	Height of the barrier, b							
	2400	2200	2000	1800	1600	1400	1200	1000
	Horizontal distance between barrier and danger source, c							
2400	-	100	100	100	100	100	100	100
2200	-	250	350	400	500	500	600	600
2000	-	-	350	500	600	700	900	1100
1800	-	-	-	600	900	900	1000	1100
1600	-	-	-	500	900	900	1000	1300
1400	-	-	-	100	800	900	1000	1300
1200	-	-	-	-	500	900	1000	1400
1000	-	-	-	-	300	900	1000	1400
800	-	-	-	-	-	600	900	1300
600	-	-	-	-	-	-	500	1200
400	-	-	-	-	-	-	300	1200
200	-	-	-	-	-	-	200	1100

Relevant Standards and Other Publications

ISO 12100	*Safety of machinery. Basic concepts, general principles for design.*
EN 294	*Safety of machinery. Safety distances to prevent danger zones being reached by the upper limbs.*
EN 349	*Safety of machinery. Minimum gaps to avoid crushing of parts of the human body.*
EN 811	*Safety of machinery. Safety distances to prevent danger zones being reached by the lower limbs.*
EN 953	*Safety of machinery. Guards. General requirements for the design and construction of fixed and movable guards.*
EN (IEC) 60204-1	*Safety of machinery. Electrical equipment of machines. General requirements.*

Chapter 12
Electrical systems

General

1. There are 2 principal Standards which contain recommendations of direct relevance to the electrical equipment in amusement devices and which form the basis of the guidance in this Chapter.

(a) The first standard is EN 60204-1. This harmonised European standard covers the safety-related aspects of electrical equipment of machines and is directly relevant to the electrical equipment used on amusement devices.

(b) The second standard is BS 7671 which sets out comprehensive standards for the design, selection, erection, inspection and testing of electrical installations. It is relevant to the power supply to, and power distribution systems on, amusement devices.

2. HSG175 deals with safe use of electrical equipment, at Fairgrounds and Amusement Parks, and contains some information relevant to designers.

Hazards and Risks Covered

3. This guidance is aimed at minimising the risk of injury from electric shock, burn, arcing and explosion, as well as protecting the equipment in the amusement device from the effects of overcurrent, overvoltage and similar disturbances. Typical causes of shock and burn injuries are shown in Table 12.1 below.

Table 12.1 Typical sources of shock injuries and burn on Attractions

Shock	Burn
Contact of persons with exposed conductive parts which have become live under fault conditions - "indirect contact"	Arcing of do supplies, e.g. at switches, terminals, etc Flashovers due to insulation failure
Contact of persons with live parts - "direct contact" exemplified by:- • Live conductors exposed in damaged cables • Exposed live terminals • Live track (on ghost trains, dodgems etc.)	Overheating leading to hot surfaces or fire (common causes are arcing and overloading) Contact with live conductors (electrical burns) Contact with surfaces that are hot under normal conditions (e.g. tungsten halide lamps or their surroundings)

Protection against Electric Shock and Burns

Prevention of Direct Contact

4. Prevention of injury by direct contact with live conductors energised at dangerous potentials [21] will generally be achieved by

[21] Live conductors above 25Vac or 60V ripple free dc

(a) covering the conductors with suitably-rated insulation which is protected against mechanical damage, or

(b) by placing the conductors in positions that will prevent them being touched, or

(c) by providing enclosures to prevent access to them.

5. It is foreseeable that access may be gained to any electrical enclosure on an amusement device by persons (e.g. operators / attendants) who do not have the required level of competence to ensure electrical safety. There are also extra risks, such as falls from height, or restricted access associated with the sometimes difficult access to panels on amusement devices which may also affect competent persons.

(a) In order to prevent injury by persons touching uninsulated live conductors inside the enclosures, equipment should be designed so that controls and devices which may need to be reset, such as circuit breakers and motor overloads, are readily accessible without exposing live parts which may be dangerous by, for example, putting these switches or controls in a separate enclosure with no live parts exposed or by using finger proof terminals and fully insulated conductors for all other items in the same enclosure.

6. Suitable measures to prevent direct contact with conductors energised at hazardous voltages may include a combination of

(a) components that have finger proof terminals (Ingress protection rating of IP2X as defined in BS EN 60529)

(b) conductors including busbars that are individually sleeved or insulated; or

(c) the placing of non-conducting barriers or shields (perspex, polycarbonate, etc.);

(d) interlocking the door of an electrical enclosure with an isolator so that the door can only be opened when the isolator is off and the isolator can only be turned on when the door is closed.

i. All parts inside the enclosure that remain live after the isolator has been turned off shall be protected against direct contact to at least IP2X.

ii. The interlock may need to be overridden to allow testing and fault finding work to be carried out, in which case the following provisions apply:

a. defeating the interlock must only be carried out by electrically qualified personnel with the competencies required for undertaking live work; advice on this and the associated safety precautions must be contained in the instruction manual.

b. it must be possible for the isolator easily and readily to be turned off while the interlock is defeated. It is preferable that, in addition, there should be an alternative means of isolation in the power circuit up stream of the enclosure in which the interlock is defeated.

The above list is not exhaustive and reference may be made to Standards and other guidance material for further information.

7. If a screen or barrier is used to protect a group or number of items it should be designed in such a way that the switchgear and control gear that requires manual operation can be operated without the removal of the screen or barrier.

8. Designers should take steps to prevent foreseeable misuse of electrical equipment by, for example, providing robust locking facilities on enclosure doors and ensuring that equipment is of robust construction.

9. Where devices such as slip rings, live rails and pick-ups allow access to live exposed conductors they should be protected to a minimum standard of not less than IP2X except when rails,

conductive floors and ceilings are part of a Protective Extra Low Voltage (PELV) or Separated Extra Low Voltage (SELV) system.

Protective Extra Low Voltage (PELV) or Separated Extra Low Voltage (SELV)

10. PELV is defined in BS EN 60204-1 and both PELV and SELV are defined in BS 7671.

11. Sources for SELV must not have any connection between the output connections and any protective earthing circuit, even accidentally, and must have the maximum voltage restricted to 25 V a.c. or 60 V d.c. with a maximum ripple of 10% rms.

12. PELV sources are also restricted to a maximum voltage of 25 V a.c. or 60 V d.c. with a maximum ripple of 10% rms and they can only be used in dry locations and when large area contact of live parts with the human body is not expected, unless the maximum voltage is restricted to 6 V a.c. or 15 V d.c.

13. PELV sources have one side of the circuit connected to the protective bonding circuit therefore, in circumstances where it is foreseeable that faults may occur which can lead to the protective conductor becoming energised at voltages in excess of 25 V a.c. or 60 V d.c., SELV systems, are preferred.

14. The electrical risks, and recommended protective measures, associated with the operation of dodgems where voltages in excess of PELV and SELV are used are discussed in the specific annex.

Prevention of Injury by Indirect Contact

15. Precautions should be taken to prevent injury from exposed metalwork of the attraction becoming live under fault conditions at voltages and for lengths of time that may cause injury.

16. In a.c. systems this is commonly achieved by providing a system of earthed equipotential bonding and automatic disconnection of supply (EEBADS). This necessitates coordination between the type of electrical supply, the earthing system, the impedance of the different elements of the protective earthing and bonding system, and the characteristics of the devices such as fuses and circuit breakers used to detect excess of current and automatically to disconnect the supply.

17. Traditionally, many amusement devices with d.c. equipment have been supplied from generators which are not referenced to earth, i.e. where neither pole of the d.c. supply is deliberately connected to earth.

18. Key points for designers of attractions are

(a) There should be a terminal provided on the amusement device where the electrical supply is brought in to allow the circuit protective conductor from the source of supply to be connected to the bonding conductors which connect together all exposed conductive parts of the attraction.

(b) The minimum cross sectional area of the protective and bonding conductors should be selected according to the guidance in EN 60204

(c) Metallic structures of attractions and parts of attractions, including items such as pay boxes, chassis and frames, should be electrically connected (bonded) together.

(d) Bolted or similar mechanical connecting methods on the rides and / or structures may be used to provide continuity of the bonding conductor, provided that these mechanical connectors do not contain any insulating insert and are tight and free of corrosion.

(e) The conductivity of these parts of the ride and / or structure should be verified on initial manufacture and, if necessary, additional bonding conductors should be provided. Where the electrical risk justifies it, flexible conductors should be used to connect across discontinuities such as slotted joints, hinges and pins.

(f) Where slip rings are used to transmit power, an earth slip ring should be provided and used; bearings are not suitable for this purpose

(g) Where protective devices such as HRC fuses and circuit breakers are used to provide automatic disconnection on attractions that use the EEBADS technique, they should be installed and rated to ensure that

i. fixed equipment is disconnected from the supply under short circuit and earth fault conditions, in a disconnection time not exceeding 5 secs; and

ii. portable and handheld equipment is disconnected in a time not exceeding 0.4 sec.

(h) The excess current circuit protection should be installed in

i. all phase conductors of referenced a.c. systems;

ii. the live conductor of 2-pole referenced d.c. systems; and

iii. all live conductors of unreferenced a.c. and d.c. systems but not circuit protective conductors.

19. As an alternative to earthed equipotential bonding and automatic disconnection, amusement device designers may provide protection by

(a) the use of Class II equipment with double or reinforced insulation; or

(b) the use of electrical separation and PELV / SELV systems.

Residual Current Devices

20. For supplementary protection against electric shock on a.c. systems the designer should specify a residual current device (RCD), with a maximum sensitivity of 30 mA, no adjustable time delay, and disconnection time not exceeding 40 ms for a residual operating current of five times the sensitivity rating (i.e. for a 30 mA RCD this would be 150 mA) on earth-referenced systems supplied at a voltage exceeding 100 V a.c., which in turn supply:

(a) circuits which are likely to be used to supply portable equipment outdoors.

(b) socket outlets on an amusement device.

(c) theme lighting, although advice should be sought from the manufacturer of the RCD if dimmer and solid state control of the lighting is used since these may interfere with the operation of the RCD. RCD supplementary protection is only necessary where the luminaires are within reach of members of the public or by operators and attendants going about their normal duties.

21. The hazards and risks arising from loss of supply to lighting and motive power, as a result of disconnection by unwanted tripping of RCDs should be considered. (see later paragraphs referring to emergency lighting.)

22. More than one RCD may need to be specified to provide discrimination, and in particular to prevent power to the entire attraction being disconnected as a result of a single fault. Discrimination can normally be achieved by using RCDs with suitable time delays. Each RCD should be:

(a) as close as practicable to the supply of the circuit it protects

(b) easily accessible

(c) easily reset

Protecting systems against fault currents

23. Each system and its constituent parts should be designed to withstand without danger the effects of overcurrent and the maximum fault current which could occur as a result of short circuit or earth faults. Table 12.2 shows the differences between overload and short circuit faults.

Table 12.2 Typical differences between overload and short circuit fault currents

Example for a system with a 240 V ac supply, with cables rated at 30 amps, and a maximum load current of 20 amps

	Overload	Short circuit
Likely cause	Too many appliances on circuit or a stalled motor	Direct connection between live-live, live-neutral or live-earth
Magnitude of current depends mainly on	Number and rating of appliances connected or, in the case of the stalled motor, the circuit impedance.	For earth faults, the earth fault loop impedance For short circuit faults, the overall circuit impedance. In both cases, the lower the impedance, the higher the fault current.
Likely effect	Slow burnout of circuit – may cause fire	Rapid burnout of circuit – may be explosive
What to specify on circuit protective device	Nominal rating of device to be between 20 and 30 amps. Current causing effective operation of the device to be less than or equal to 43.5 amps (1.45 x 30)	Nominal rating of device to be between 20 and 30 amps. Current causing effective operation of the device to be less than or equal to 43.5 amps (1.45 x 30). Fault breaking capacity (i.e. the current the protective device can safely disconnect) to be greater than the prospective short circuit current.

24. There are two things the designer needs to consider in protecting against fault currents - system protection and coordination as described in paragraph 22, and the correct rating of the switchgear, equipment and cables protected.

25. System protection is achieved by specifying HRC fuses and / or circuit breakers to interrupt the supply if there is a fault or overload. The designer should make sure that both the nominal rating and fault breaking capacity of each protective device are specified and are sufficient for the intended use.

26. The current carrying capacity of switchgear, cables and equipment should be greater than the rating of the protective devices on the circuits supplying them. Protective switchgear should be rated such that it can withstand the maximum through fault for either 1 second or 3 seconds, depending upon the design specification of the installation or system. Note that changing the specification of a cable may not only change the fault current rating of the installation but, because the earth loop impedance is likely to be altered, also the value of the fault current itself.

Means of disconnecting (isolating) and functional switching of the supply

27. All attractions should be designed with means to disconnect (isolate) the supply to all live conductors. Suitable means of disconnection are listed in EN 60204-1. When used for achieving isolation, the disconnecting device should have a means permitting it to be locked in the off (isolated) position (e.g. by padlocks). Also, devices used for isolation must have a visible gap or a position indicator that conforms with IEC 60947-3.

28. Functional switching and disconnection for isolation should apply as a minimum to the following conductors :

Table 12.3	**Disconnection of conductors for isolation**
three phase	all three phases
three phase and neutral	all three phases[22]
single phase referenced to earth	phase and neutral
single phase not referenced to earth	both phases
single phase centre tapped	both live conductors at the supply and at each individual consuming unit.
d.c. not referenced to earth	positive and negative
d.c. referenced to earth	positive

29. Where the means of switching the supply is by way of a plug and socket, the circuit protective conductor should make first and break last and the rating of plug and socket should not exceed 16 A.

30. For a.c. and d.c. systems not connected to earth, the means of cutting off the supply must break both poles, e.g. if a knife switch is used for disconnection, it must be a double knife. (Domestic switches are normally single pole only and are therefore unsuitable for this purpose).

31. Each motor circuit should be designed to contain a readily accessible isolator which may be used to cut off power to the motor and all associated equipment, including any automatic circuit breaker. (Not all switches, switch fuses, circuit breakers are capable of being used as isolators. Electromagnetically operated or semi-conductor contactors or motor starters are not isolators).

32. Isolators are needed at :-

(a) the point of supply

(b) other locations where equipment can be conveniently isolated

(c) each item of equipment where it cannot be isolated as a group

33. In considering the location of such isolators, the following should be considered :-

(a) The distance of the isolator away from the motor.

(b) The risk of persons not isolating due to the distance required to get to the isolator.

(c) The risk of persons not isolating due to difficult, or time consuming access to the isolator, such as when it is located at the bottom of a roller coaster or log flume escalator, when the relevant motor is at the top.

Ingress Protection class of equipment and components

34. The degree of ingress protection of plugs, sockets, connectors, conduit, trunking, enclosures, fittings and other equipment shall not be less than IP2X when installed in closed rooms or where protected from the effects of the weather, although IP44 shall be specified where there is a possibility of the equipment and components being subjected to moisture or dust.

35. Equipment and components installed in all other areas should have ingress protection of not

[22] Neutral may also be disconnected but it should break after or at the same time as the phase conductor and be remade before or at the same time as the phase conductor

less than IP65

Protection against effects of lightning, static discharges and switching surges

36. On most attractions no additional provisions for lightning protection are required. However, in this respect designers should consult BS 6651 or ENV 61024-1 for guidance on how to carry out lightning risk assessments and on precautions that may need to be taken.

37. Some amusement devices suffer from static discharge, as passengers leave or enter the device, due to the composition of some types of running gear etc. Normal earthing procedures should eliminate this; however it may be necessary to fit extra earthing arrangements to devices such as non-powered roller coasters, that would not normally have any earth connection. Such arrangements may only need to be activated immediately prior to disembarkation or embarkation, subject to risk assessment.

38. Where electrical equipment may be subject to transient overvoltages due to switching surges, the designer should consider the need for overvoltage suppression devices to be fitted to the incoming terminals of the supply disconnector.

Generators, rectifiers and transformers

39. Designers of amusement devices need to take account of the nature of the electrical supply to the device and must provide information to the users of the device on the nature of the required electrical supply and earthing arrangements.

40. Permanent supplies from electricity companies will normally have an associated earth conductor connected to the star point of the company's distribution transformer, either directly or as part of a combined neutral / earth conductor. Provision should be made on an amusement device likely to use external supplies to connect the incoming earth to the device's main earth terminal.

41. On a.c. generators supplying amusement devices, the star point (or neutral) should be connected to the frame of the generator and the circuit protective conductors and bonding conductors connected to the frame. Where practicable, the frame should be connected to earth using suitable earth electrodes or mats.

42. Small single phase generators rated at less than 5 kVA and supplying single amusement devices such as bouncy castles via short lengths of cable (less than 10 metres) may be used as unreferenced isolated supplies, provided that the cables are suitably protected against mechanical damage and that the exposed metalwork of the amusement device is bonded to the frame of the generator.

43. D.C. generators are normally operated as unreferenced supplies, but the protective and bonding conductors for the connected attractions should where possible be connected through to the frame of the generator.

44. Equipment used to provide d.c. supplies should be configured so as to limit the ripple on the supply to the levels specified for PELV and SELV systems, but see Annex 1 for the requirements relating to dodgems.

45. Adequate measures should be provided at the generator output distribution point in order to protect all outgoing cables against overload and short circuit. Any such protection should take account of the actual size of conductors used to supply equipment, and be in accordance with BS7671.

46. Any circuit breaker or fuse device should not have a current rating higher than the rated maximum current carrying capacity of any cable connected to that circuit breaker or fuse.

47. It should be ensured that the earth loop impedance, of any distribution system or ride feeder system, is co-ordinated with the associated generator output circuit breaker or fuse, so that the maximum disconnection times required by BS 7671 are not exceeded.

48. Secure mountings should be specified for the generator including, if necessary, anti-vibration mountings on the generator or immediately adjacent.

49. Adequate ventilation should be specified for enclosures to contain rectifiers or transformers.

50. It is necessary to ensure that there is clearly visible information marked on generators (this may include information necessary to the user e.g. voltage, connection information, minimum cable sizes, correct fuses, maximum load, frequency and earthing requirements).

Motors

51. Motors should be provided with readily accessible means of starting and stopping, including in emergency. Motors driving rides should be fitted with systems to prevent them restarting automatically, either when power is restored after an interruption to the supply or when resetting circuit breakers or overload protection devices.

Lighting and audio systems

52. All parts of an amusement device around which persons may circulate, including access and egress, should be provided with sufficient illumination to ensure safety, bearing in mind the intended times and locations at which the device may be used.

53. In locations where amusement device controls are to be operated, and in electrical switch-rooms, there must be adequate and sufficient lighting available at all times.

54. Light fittings and speakers should be designed :-

(a) to be securely attached to the structure, battens or support wire intended to carry them, i.e. the support structures and the equipment should be sufficiently strong in all foreseeable environmental conditions (including wind);

(b) not to rely on electric cable conductors to carry their weight, inclusive of any attachments, unless the cable is specifically designed for this purpose;

(c) not to be exposed to moisture unless designed for such exposure;

(d) to be placed out of reach unless precautions are taken to protect against shock and burn (e.g. in the event of broken fittings leaving filaments exposed);

(e) to be protected against damage in attractions where projectiles are used

Emergency lighting

55. All parts of an amusement device around which persons may circulate, including access and egress, should be provided with sufficient emergency escape lighting, bearing in mind the intended times and locations at which the device may be used.

56. In the case of devices deliberately designed to be operated in dark conditions, emergency escape lighting should be provided which should comply with BS 5266-1 and EN 1838.

57. If at any time there is a failure of the lighting in a structure containing amusement devices, the parts of the structure affected, including any exit signs, should immediately be illuminated by emergency escape lighting.

58. Emergency escape lighting may be supplied from the same source as the normal lighting, but should also be capable of being powered by an independent supply. The independent supply should be brought into operation immediately and automatically in the event of failure of the normal supply.

59. Where batteries are specified as the means of powering emergency escape lighting, the designer should provide instructions for checking and ensuring that adequate charge will be available at all necessary times.

60. Any area entered or used by operators or attendants shall be provided with standby and / or escape illumination as above.

Additional requirements for water rides

61. Water rides that use electrical systems such as electrically driven water pumps have the potential for increased risk of electrical injury and, as a consequence, special precautions must be taken. BS 7671 and its supporting Guidance Note 7 Special Locations provide comprehensive guidance on the measures that should be taken in locations where the presence of water increases the risk of electrical injury. Designers of water rides and similar amusement devices should refer to these publications.

Provision of Information about Supply Requirements

62. The following data should be marked on a plate at the point of connection of supply to an amusement device and repeated in the Operations Manual

(a) Minimum / Maximum power requirements

(b) Voltage

(c) If AC, the number of phases, the frequency in Hz, and whether or not a neutral connection is required.

(d) Maximum allowable Ze (earth loop impedance at that point).

Relevant Standards and Other Publications

BS EN 1838	*Lighting applications. Emergency lighting.*
BS EN 60204-1	*Safety of machinery. Electrical equipment of machines.*
BS EN 60529	*Specification for degrees of protection provided by enclosures (IP code).*
ENV 61024-1	*Protection of structures against lightning. General principles.*
BS 5266-1	***Emergency lighting. Code of practice for the emergency lighting of premises***
BS 6651	*Code of practice for protection of structures against lightning.*
BS 7671	*Requirements for electrical installations. IEE Wiring Regulations. Sixteenth edition.*
HSG 175	*Fairgrounds and amusements parks: Guidance on safe practice.*

Chapter 13
Information to be provided by Designers

General

1. So far as the safety of a particular design of amusement device is concerned, the Health and Safety at Work etc Act 1974 (as amended particularly by the Consumer Protection Act 1987), and associated Regulations, apply in Great Britain. Under section 6(1A) of the Act :-

(a) " It shall be the duty of any person who designs, manufactures, imports or supplies any article of fairground equipment'[23]

(b) ... ;[24]

(c) ...

(d) to take such steps as are necessary to secure that persons supplied by that person with the article are provided with adequate information about the use for which the article is designed or has been tested and about any conditions necessary to ensure that it will be safe and without risks to health at all times when it is being used for or in connection with the entertainment of members of the public; and

(e) to take such steps as are necessary to secure, so far as is reasonably practicable, that persons so supplied are provided with all such revisions of information provided to them by virtue of the preceding paragraph as are necessary by reason of its becoming known that anything gives rise to a serious risk to health or safety."

2. The industry associations that endorse this guidance, with the support of the Health and Safety Executive, are concerned that the law shall be followed and, to help to demonstrate that it is, they have put in place some amusement device safety principles which must be followed by their members if they are to operate in Great Britain. One of the fundamental safety principles is that :

(a) The significant risks associated with safety-related work potentially affecting an amusement device are formally checked and thereby require the agreement of an independent party that the primary duty holders (designers, in this case) have adequately controlled any associated risks.

3. Safety-related aspects of designers' duties are independently checked in a process known as "Design Review". A second fundamental principle relates to those persons carrying out the checks :-

(a) Such individuals, and the firm or business for whom they work (known as an "inspection body"), are required to meet specified competence requirements, including minimum qualifications, experience and training appropriate to the particular types of work for which they claim competence. The details have to be registered annually with an agreed registration body which carries out a range of appropriate checks on their validity.

4. Then, a third fundamental principle relates to the independence of the inspection body and their personnel from those whose work they are checking :-

(a) The inspection body shall be independent of other parties involved.

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[23] *"article of fairground equipment"* means any fairground equipment or any article designed for use as a component in any such equipment.
Note also that section 6(1) includes similar duties regarding safety during installation, maintenance etc.

[24] Subsections 6 (1A) (a) & (b) have been omitted here for reasons of clarity.

(b) The inspection body, and its staff responsible for carrying out the inspection (in this case the "Design Review") shall not be the designer, manufacturer, supplier, installer, purchaser, owner, user or maintainer of the items which they inspect, nor the authorized representative of any of these parties.

(c) The inspection body and its staff shall not engage in any activities that may conflict with their independence of judgement and integrity in relation to their inspection activities. In particular they shall not become directly involved in the design, manufacture, supply, installation, use or maintenance of the items inspected.

5. The industry believes that its commitment to these 3 principles - of double-checking, registration of competence of those carrying out checks, and independence from conflicting influences on their checking work - helps to ensure greater public safety.

6. Where a design combines a number of different disciplines and / or persons, any person commissioning design work, or any person who imports, should appoint a design project safety co-ordinator (which may be himself if he has appropriate competence) and inform the relevant parties in writing. That person should check the way in which the elements combine and should ensure that every safety-related aspect has been covered.

7. In order for the necessary checks to be carried out and for controllers of amusement devices and their staff to be able to maintain and operate their equipment in a way which ensures safety, appropriate documentation must be made available. This needs to be in English and the language of the controller. The main elements of this should be as follows below:

Information to be used in Design Review

8. Designers need to make technical information available to enable Design Review to be carried out. More details about this process may be found in a sister publication[25] but it should be noted that the inspection bodies carrying out this work are required to ensure confidentiality of commercially-sensitive information which does not need to be divulged for safety reasons.

9. The information that needs to be passed on to the amusement device controller should be included but needs to be supplemented by the following more specialised technical information :-

(a) design risk assessment documentation (see Chapter 1);

(b) assessments, or checks that have been carried out, relating to functional safety, installation, testing, commissioning

(c) details of any modifications to the original design together with details of checks that have been made regarding such modifications;

(d) information on the correct configuration of equipment and computer systems;

(e) description and relevant up-to-date drawings of the components used, how they should be correctly assembled and the correct setting of adjustable features;

(f) instructions for installation and commissioning;

(g) instructions provided for the user which specify the actions necessary to maintain safety during operation and maintenance, including details of when operational and proof checks should be done;

[25] *Safety of amusement devices: Inspection;* to be published by ADSC on behalf of the industry associations endorsing the British guidance documents (i.e. ACES, AIS, ALES, BACTA, BALPPA, SGGB, SIRP, NAFLIC) in partnership with the HSE.

(h) in-service NDT schedules based on calculated fatigue lives (NDT schedule);

(i) information on possible fault conditions and their significance for safety.

Information to be used by the controller in the Operations Manual

Information on design and manufacture

10. The manual needs to contain certain specific information on design, including:

(a) a summary of salient safety features;

(b) a summary of design and required manufacturing standards (materials, quality control, etc);

(c) the design specification, including, where possible:

i. the grade and dimensions of any bolts, screws and rivets whose failure could cause danger;

ii. specifications and manufacturers' names for proprietary assemblies such as motors, gear boxes, pumps, hydraulic cylinders, etc.

Relevant drawings or diagrams

11. The manual needs to contain relevant drawings or diagrams, including:

(a) outline drawings, showing the main dimensions of the device when assembled and the recommended safe clearance distances when in motion;

(b) a plan showing the weight distribution and recommended packing points, together with the maximum permitted load at each point and any foundations required;

(c) the interrelationship of regularly assembled parts, with each part identified by a unique number where appropriate;

(d) diagrams of all control systems (hydraulic, pneumatic, electrical) according to ISO standards together with program listings, etc, for all programmable and non programmable electronic systems (PLCs, drive parameters, etc).

Replacement parts

12. The manual needs to contain a full list of replacement parts and their reference numbers.

Information on transport, installation, erection, dismantling

13. The manual needs to contain information on transport, installation, erection and dismantling, including:

(a) diagrams to show the correct assembly of the component parts;

(b) a key to the identification of non-interchangeable parts;

(c) information on the correct use of any special equipment required for assembly;

(d) procedures for setting up and dismantling the device correctly including, where relevant, details of:

i. any safe systems of work required;

ii. advice on ground or foundation preparation;

iii. order of assembly / disassembly of component parts;

iv. any temporary measures needed to support a partially completed device;
v. torque settings essential to the safety of screws or bolts;
vi. any procedures needed to prevent or relieve stress concentration during assembly / disassembly;
vii. jacking and packing points and procedures, including selection of materials, load spreading and ballasting where relevant;
viii. levelling and out-of-level tolerances;
ix. physical guards, barriers, fencing, etc;
x. mechanical and electrical power requirements;
xi. correct methods for connecting electrical equipment to the power supply;
xii. grounding for lightning protection;

(e) the following data regarding electrical requirements, which should be identical to that marked on the plate at the point of connection of supply to an amusement device :

i. Minimum / maximum power requirement
ii. Voltage
iii. If AC, the number of phases, the frequency in Hz, and whether or not a neutral connection is required
iv. Maximum allowable Ze (earth loop impedance at that point).

(f) any checks or testing needed to make sure the device has been assembled correctly and is functioning in the intended manner.

Information on safe use

14. The manual needs to contain information on:

(a) safe use, including:

i. a description of the normal functioning of the device (including the function and motion of the major components);
ii. the normal safe operating procedure (including the functions and responsibilities of the operator and attendants);
iii. details of operating speeds. The maximum or limiting speed should not be based solely on the forces that the device can withstand but should also take account of the need to prevent injury to users;

(b) loading which should specify:

i. the maximum working loads;
ii. maximum passenger numbers;
iii. permissible out of balance loading;
iv. order of passenger loading;

(c) limitations to use, e.g.

i. passenger dimension (size, weight), medical condition,

ii. adverse environmental conditions (particularly wind speed);

(d) details of any passenger containment system and guidance on its use;

(e) information on relative positioning of passengers in the same car;

(f) detailed explanation of the controls and their function;

(g) safe passenger access;

(h) limitations required to prevent overload of the structure in waiting areas;

(i) faults and fault finding, including indications of malfunction and the action to be taken;

(j) emergency procedures.

(k) evacuation procedures.

Instructions and guidance on any maintenance and inspection

15. The information needs to cover:

(a) components which require regular lubrication including information on suitable lubricants and the frequency required;

(b) components which require regular replacement and the period between replacement;

(c) components which require inspection for wear and fatigue, correct setting etc, together with details of the correct settings and allowable tolerances;

(d) electrical equipment together with any checks to be done by the user and details of safe isolation procedures;

(e) maintenance and testing of controls and interlocks.

Information relating to Examination and testing of the device once in use

16. Safety-critical components need to be identified and estimates given of their likely life. It is important that the documentation is adequate (e.g. by the inclusion of drawings or photographs) to identify the safety-critical regions of these components to those who will subsequently have to inspect them.

(a) Inspection or examination intervals need to be specified as well as the type of techniques to be used, e.g. visual or NDT, and criteria for acceptance / rejection.

(b) Where appropriate reference material relating to the original condition can be included, e.g. the results of original NDT or measures of the performance of safety-critical components or systems. Guidance should also be given on the parts which should be covered by the daily and other periodic checks.

17. A NDT schedule should be prepared by the designer, which should take account of calculated fatigue lives, revised in the light of information received from inspection, testing, operation, etc. For further information see Chapter 4.

18. It is important to record as much information as possible about the original as-built condition of the device for two principal reasons.

(a) Firstly, such information can be critical to the accuracy of initial design assumptions and it is vital that this information is fed back to the designer and design reviewer so that the accuracy of these assumptions can be checked.

i. Any necessary alterations to, for example, fatigue life assessments and consequent NDT schedules can then be implemented (eg. as a result of unexpected secondary accelerations caused by variations in accuracy of a ride track or play in rotating elements, etc).

(b) Secondly, it provides a benchmark of the condition of the device, which is vital for future inspections in terms of determining the amount of wear, degradation of components, etc (e.g. the amount of play in slewing rings, bearings, bushes, etc, under prescribed, repeatable test conditions, the settings of adjustable parameters, etc).

i. It is important that this information is considered in relation to the design parameters and assumptions, its significance to those parameters and assumptions is carefully assessed and the designer alters any information they need to provide accordingly. Any such alteration to this information also needs to be subject to Design Review.

Appendix 1
Common amusement device hazards

1. The following Table A.1 lists some of the more common hazards associated with fairground and amusement park machinery and structures.

2. The right hand column indicates Chapter numbers in this publication which contain text relating to the particular hazard.

3. Chapter 1 explains the process by which risk assessment associated with a particular hazard should be carried out.

4. The Table is not claimed to include every amusement device hazard that may exist, nor does this publication address all of those listed. The designer should identify any additional significant hazards for risk assessment in accordance with Chapter 1.

Table A.1 Some hazards associated with amusement devices

Hazards		Refer to Chapter
Falls of persons (also slips and trips)		
	On flat (e.g. poor surfaces, inadequate lighting)	11
	From one level to another	11
Persons (including employees and bystanders) struck by falling or ejected objects		
	Passengers' belongings	
	Mechanical / structural or other parts coming unfastened or failing in service (including backdrops, scenery, light fittings, speakers)	4,6
	Tools	
	Ejected passengers / employees	2,10
Persons (including employees and bystanders) struck by other objects		
	Airgun pellets	
	Arrows / darts	
	Other projectiles	
Hazards arising from raised anxiety states affecting vulnerable persons		
	Persons with heart problems	
	Pregnant women	
	Mentally impaired passengers	
Hazards arising from forces of motion on passengers		
	Nausea	2
	Physical damage resulting from intensity, direction and duration of accelerations and jerks (i.e. change of accelerations)	2,10
Hazards associated with passenger containment		
	Ejection of passenger	2,10
	Effect of forces exerted by elements of containment	2,10
	Movement of passenger unit while loading / unloading	8,9
Hazards from impact/ collision		

Table A.1 Some hazards associated with amusement devices		
Hazards		**Refer to Chapter**
	Collision of passenger unit with pedestrians (land trains etc.)	
	Collision of passenger unit with structures	
	Collision with another vehicle (e.g. Dodgems, multiple unit roller coasters)	9
Hazards from motion relative to, contact with, or proximity to, machinery		
	Squeezing / crushing	10
	Cutting / severing	10
	Shear traps	10
	Entangling (including ride passengers' hair and clothing)	
	Struck while moving / reaching into or out of	11
	Asphyxiation / poisoning / nausea etc. from contact with or inhalation of dust, fluids, gases, mists, fumes, vapours	
	Burning by high temperature surfaces	11
	Electric shock	12
	Hearing or other damage from high noise levels	
Positional instability of amusement device including wind effects		
	Overturning (including the possibility of inadequate foundations or packing)	6
	Sliding off packing	6
	Lifting off	6
Structural / mechanical breakage		
	Static failure following from :-	
	Loadings not properly accounted for; including overloading, excessive out-of-balance loading, wind and snow loading (earthquake not relevant in UK)	3,6
	Calculation error	
	Fatigue failure following from :-	
	Inadequate dynamic analysis or stress analysis	2, 3, 4
	Structural / mechanical vibrations unaccounted for	2
	Secondary dynamic effects unaccounted for	2
	Inspection regime not consistent with calculated fatigue life	4
	Failure or seizure as a result of wear, corrosion or rot	
	Escape of liquids / gases under pressure (hydraulic / pneumatic systems) as a result of poor design or in-service deterioration	7
Hazards associated with electricity		
	Electric shock or burn by direct contact with live parts	12
	Electric shock or burn by contact with parts which have become live under fault conditions	12
	Arcing	12
	Static discharge	12

Table A.1 Some hazards associated with amusement devices		
Hazards		**Refer to Chapter**
	Explosion	12
	Lightning strike	12
	Fire risk	12
Hazards associated with controls / control systems		
	Over/under speed	9
	Inadequate braking	8,9
	Excessive braking	8,9
	Inadequate operational, safety, or emergency stops	9
	Insufficient safety integrity	9
	Software errors	9
	Over-reliance on operator / attendant judgement or skill	
	Unauthorised tampering (e.g. resetting by staff, access by members of public)	8
Hazards due to poor use of ergonomic principles (operators / attendants)		
	Resulting from :-	
	Inadequate design, location or identification of manual controls	8
	Inadequate design or location of visual displays	8
	Insufficient visibility of significant parts of the device from operator / attendant position	8
	Inadequate local lighting	12
	Excessive physical effort	
	Effect of exposure to noise (e.g. music)	
	Noise interference with speech communication, acoustic signals etc.	
Additional hazards associated with water (ponds, pools, log flumes, water parks, rapids rides)		
	Drowning of member of public	
	Biological or microbiological (e.g. viral or bacterial) - water quality	
	Hazards associated with underwater maintenance and inspection	
	Hazards associated with use of electricity	12
Additional hazards associated with crowds		
	Crushing due to crowd pressure	
Emergency situations		
	Fire	11
	Evacuation of members of public from enclosures (including issues such as lighting, pinch points, etc.)	11,12
	Evacuation of passengers from remote locations (e.g. following ride breakdown)	11

Appendix 2
Electrical safety of dodgem rides

Introduction

1. This appendix provides design guidance on the electrical safety of dodgem rides supplied in the UK. The electrical safety features of this type of ride are unusual because of the characteristic large areas of exposed live conductors on the floor and the net which are normally, respectively, the negative and positive poles of the d.c. supply to the dodgem cars. The main complication is that the power and current requirements of the cars, and the need to keep current-carrying cable sizes to manageable dimensions, are such that it is not feasible to restrict the supply voltage to a maximum of 60 Vd.c. The supply therefore cannot satisfy the SELV or PELV requirements that apply to other types of ride that feature exposed live conductors.

2. It is accepted that dodgem rides may be supplied at voltages exceeding the recommended limits for other fairground devices with exposed live conductors. However, in the light of this, care must be taken to ensure that users and operators of the rides and other members of the public are not exposed to unacceptable levels of risk of electrical injury. This guidance explains how this can be achieved for rides supplied from 2 types of power source; firstly, a transformer / rectifier unit and, secondly, a d.c. generator.

Basic Principles

3. A generalised configuration of a dodgem ride is shown in Figure A2.1, which is an elevation drawing showing the floor, net and support structure. In most modern ride designs the support structure is metallic, typically steel poles or lattice towers, and is electrically connected to the floor of the ride, as illustrated in the diagram. Older rides may have support structures made of wood or other insulating material.

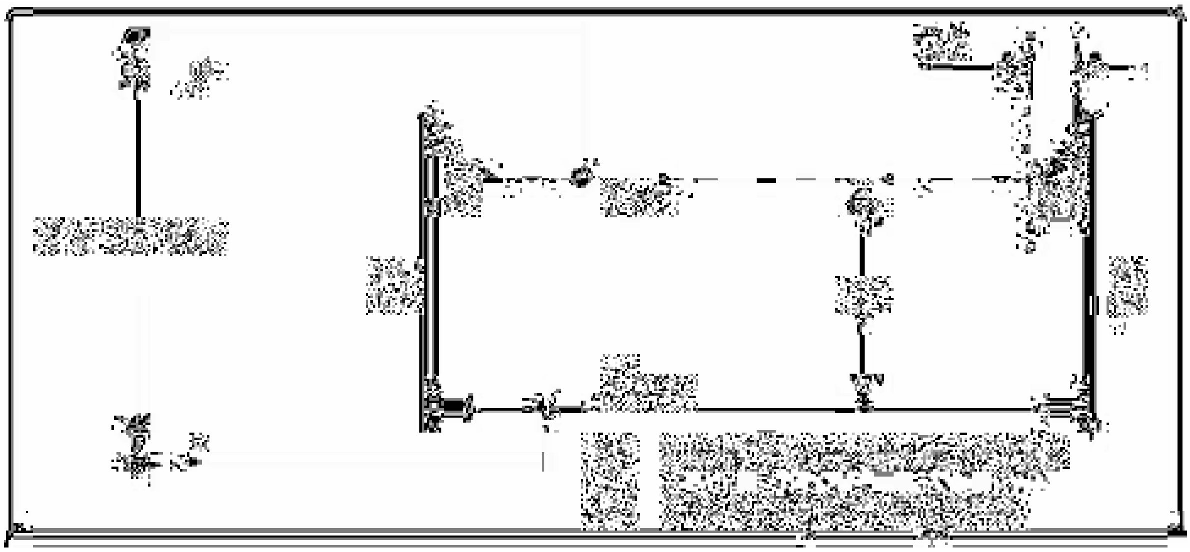

Figure A2.1 Basic Configuration of Ride (in elevation)

4. The overriding design requirement for the d.c. supply to the ride is that its mean value must not exceed 110 V and that its peak value taking account of ripple must not exceed 120 V. This voltage is generally recognised to be sufficiently low to prevent serious or irreversible electrical injury (shock and burn injuries arising from current flowing through the body) in dry conditions for the large majority of people. This is reinforced by the history of accidents on dodgems – in essence, there is no evidence that

the presence of large areas of exposed conductive parts energised at this voltage has led to injury from electric shock or bums.

5. In addition to restricting the voltage in the way described, the risk of injury from simultaneous contact between the floor and the net can be further reduced by ensuring that distance D1 in Figure A2.1 is as high as possible; typically, it will be in the order of 2 metres. Furthermore, direct contact between the 2 poles of the d.c. supply should be prevented by constructing the ride in a way that makes it difficult for persons to climb the vertical metallic members and reach over to the net.

6. On some designs of car it may be possible to contact opposite poles of the supply whilst in the car, for example by reaching under the dashboard and touching the positive connection to the motor above the front wheel whilst also touching metalwork which is at negative potential. This should be prevented by either insulation of the connection or by physical barriers.

7. Measures must also be taken to ensure that the power collectors on the top of the insulated poles on the cars cannot bridge the gap between the net and the metallic structure. If this happens, considerable arcing can occur, creating molten spatter that can cause thermal burn injuries to people using the ride. This can be prevented by ensuring that distance D2 is greater than the length of the collectors or by providing an insulating barrier between the net and the supports.

8. The design of the car should be such that it should not be possible for the pole to become displaced, so that a short circuit at the base of the pole is not possible. Such incidents have been known to happen, causing burn injuries to the riders.

Rides supplied from transformer/rectifier units

9. The general configuration of this supply arrangement is depicted in Figure A2.2, which illustrates a Class I transformer / rectifier unit fed at low voltage. The Figure excludes the start, stop and other controls for the ride. Most units of this type will be supplied at 400 V a.c. 50 Hz 3 - phase from a TN source, as shown. For clarity, later diagrams will show single phase supplies, but the safety principles apply to both three phase and single phase supply arrangements.

10. The supply into the transformer rectifier assembly must be configured as either a TN-S source, as depicted, or a TT source for the reason described later in this section.

11. It will be noted that Figure A2.2 incorporates a 'dotted' earth symbol. This has been included to show that in many applications there will be a fortuitous connection of the metallic structure to earth because the structure may be standing on the ground. For this reason, the d.c. supply to the ride should be configured as an isolated supply, meaning that there should be no deliberate connection of either pole at the point of supply on the secondary side of the transformer to a reference point, including earth; this includes the metal casing of the assembly. This will prevent return current flowing back to the transformer secondary windings through fortuitous earth paths.

12. In normal operation the configuration shown in Figure A2.2 will be safe. However, additional features are required to take account of foreseeable faults that may occur and which may lead to danger.

13. Multiple connections may be used to both the net and to the track to ensure equipotential. However, the cross-sectional area of each of the individual conductors should be equal to the main supply cable.

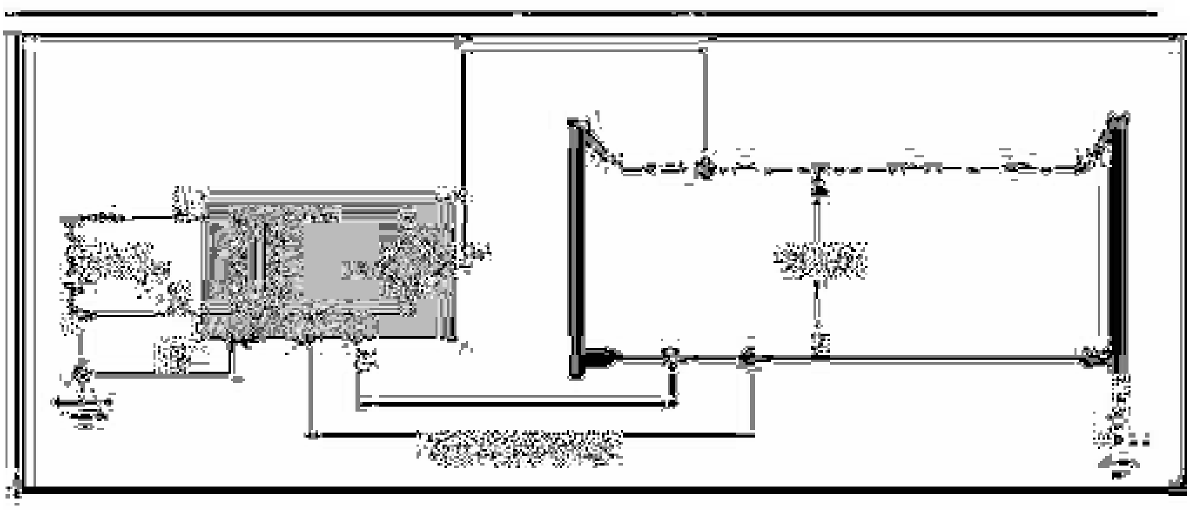

Figure A2.2 General arrangement of transformer/rectifier unit supplying a ride

14. Overcurrent protective devices should be inserted in both poles of the supply on the secondary side of the transformer to cater for conditions where excess of current will flow. This may include, for example, faults in the car motors and a short circuit fault between the net and the floor or support structures.

(a) The prospective short circuit current from the transformer will often be lower than the current carrying capacity of the cables connected to the ride, but means still need to be taken to protect against excess current flowing for extended periods of time.

(b) The rating and tripping characteristics of the overcurrent devices should be selected to take account of the maximum prospective short circuit current and factors such as stalled motor currents that will flow into the motor loads at start up and during stalled conditions.

15. In those cases where the transformer assembly is not constructed to meet the safety isolating transformer requirements set out in EN 60742 there is the possibility of inter-winding faults that may create a conducting path between the primary and secondary windings of the transformer.

(a) This would lead to dangerous a.c. voltages being present on the exposed conductive and accessible parts of the ride. To reduce the risk of danger from this type of fault, the exposed metalwork of the floor and support structure should be bonded to the exposed metalwork of the transformer / rectifier unit which, in turn, should be earthed by the protective conductor of the external supply.

(b) Note that this reinforces the need to ensure that no connection is made between the secondary side of the transformer and the casing of the unit – if such a connection were to be made, a proportion of the return current would flow through the bonding conductor and any earth paths that may exist.

(c) The cross sectional area of the bonding conductor should be at least half the cross sectional area of the d.c. cables supplying the ride.

16. In those circumstances where the transformer does satisfy the requirements of a safety isolating transformer, the bonding connection should still be made.

17. The configuration described in the foregoing paragraphs is depicted in Figure A2.3.

Figure A2.3 Recommended basic configuration[26]

18. In many circumstances there will be theme lighting and other equipment attached to the ride's support structure, as depicted in Figure A2.4.

(a) Preferably, the supplies to this equipment should be SELV but, where they exceed extra low voltage (as exemplified in Figure A2.4 for equipment supplied at 230 V a.c.), alternative precautions against both direct and indirect shock must be taken.

19. It is preferable for the equipment to be of Class II construction.

(a) Where the equipment is Class I with exposed conductive parts, there should be a supplementary bonding conductor connected between those parts and any metallic parts on the structure of the ride.

(b) The bonding conductor should be the same size as the protective conductor on the supply to the equipment.

(c) Lighting and other electrical equipment supplied with a.c. power, other than lighting provided to illuminate the ride for safety reasons (e.g. emergency exit lighting), should be protected by an RCD, or combination of RCDs, rated to trip at a residual operating current of 30 mA.

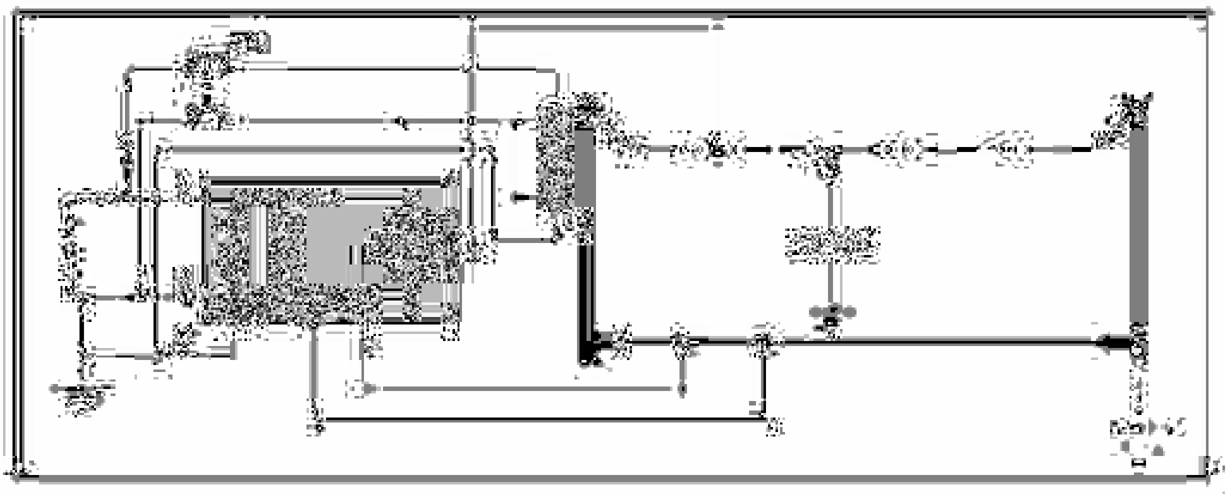

Figure A2.4

Recommended configuration with Class 1 apparatus installed on structure

20. This configuration of earthing and bonding means that the a.c. supply to the transformer must not be of the TN-C-S variety (also known as protective multiple earthing, PME, with a combined neutral earth, CNE). This is because an open circuit neutral fault on the supply could lead to the ride's exposed conductive and accessible parts becoming live at the supply's phase voltage, which would be a dangerous condition. For this reason, the supply must be either TN-S, as depicted, or TT.

21. Where a TN-C-S supply is provided by, for example, a power distribution company, the supplier's earth must not be used as the main earth connection to the ride, in which case a local earth electrode should be used as the main earth. In these circumstances, the supply to the transformer / rectifier assembly should have earth leakage protection installed in addition to the usual excess current protection.

[26] For clarity, this and later diagrams illustrate a single phase supply to the transformer assembly; in most cases the supply will be 3-phase.

Rides supplied from generators

22. The general configuration of this supply arrangement is depicted in Figure A2.5, which illustrates the dodgem ride being supplied directly at 110 V dc from a d.c. generator set. The figure does not illustrate any of the control devices needed to operate the ride.

23. The d.c. source should be operated as an isolated supply, with no deliberate connection between the windings and the frame of the generator. This prevents the flow of return current through earth paths. The only other main precaution is the provision of overcurrent protection in both poles of the supply – this is normally in the form of fuses or thermal overloads.

24. Although not essential, it is advisable to connect a bonding conductor between the live floor plates of the ride and the frame of the generator. The bonding conductor should have a cross sectional area at least half the cross sectional area of the d.c. cables supplying the ride. The main purpose of this is to maintain the floor and support structure at the same potential as the generator's frame.

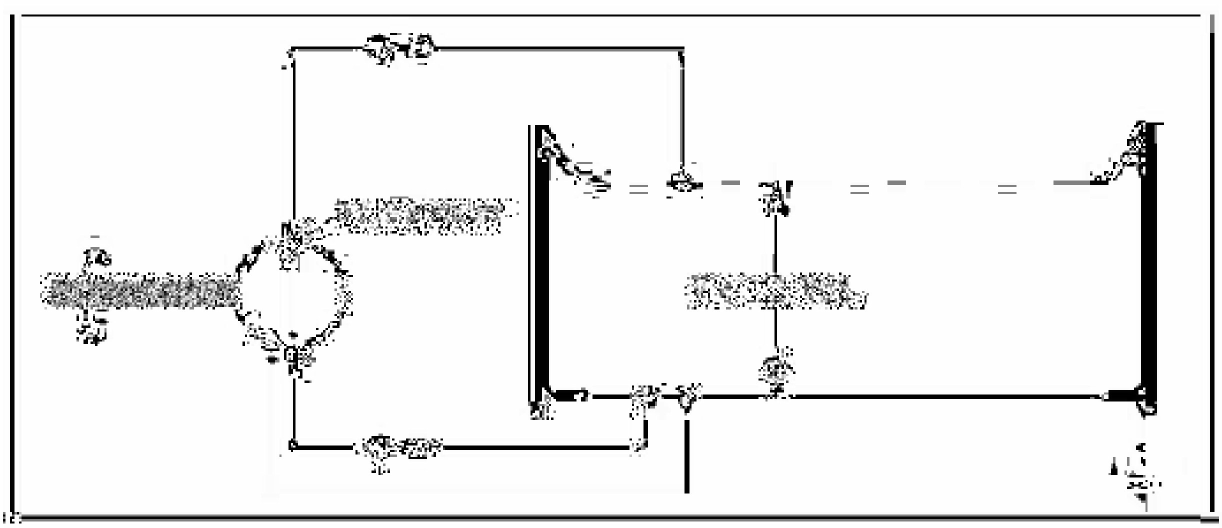

Figure A2.5 General arrangement of ride supplied directly by d.c.. from generator

25. Where the design of the ride incorporates theme lighting and other electrical equipment, precautions must be taken against direct and indirect shock injuries. Preferably, the supplies to this equipment should be SELV but, where they have to exceed extra low voltage for sound engineering reasons, alternative precautions against both direct and indirect shock must be taken. The bonding conductor connecting the exposed metalwork of the a.c. equipment to the structure of the ride should be the same size as the a.c. system's protective conductor

26. Class II equipment is preferred, but Figure A2.6 illustrates the situation where an item of Class I equipment such as theme lighting is supported on the metallic structure of the ride. This equipment is supplied at 230 Vac from a separate a.c. generator. In this case, the a.c. supplies are referenced to earth and to the a.c. generator frame, so the a.c. generator supply must be treated as a TN source.

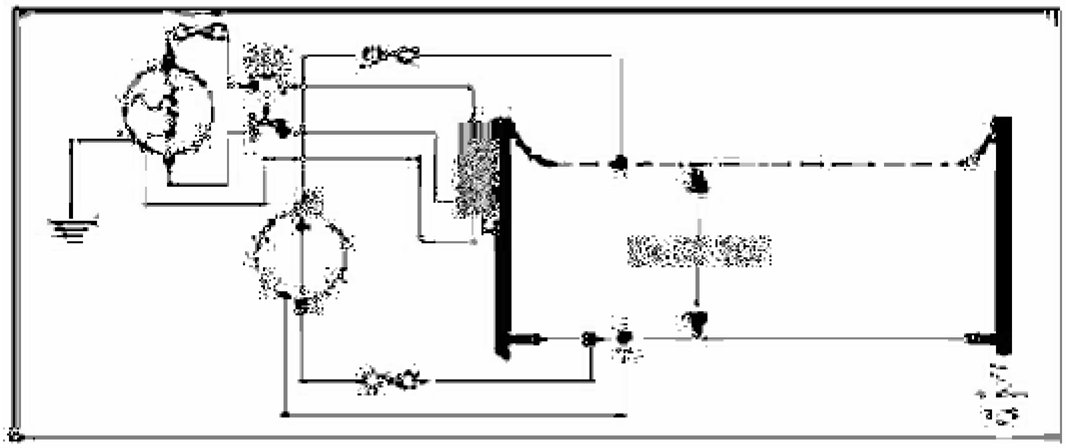

Figure A2.6 Dodgem supplied from d.c. generator with theme and other equipment supplied from a.c. generator (other than SELV and PELV supplies)

27. In some cases the a.c. and d.c. generators are mounted in the same generating set in a so-called piggy-back configuration. In these circumstances the frames of the d.c. and a.c. sets are electrically bonded together. An insulation failure between the windings of the d.c. generator and its frame can lead to d.c. fault current flowing through the bonding conductor and the a.c. system's protective conductor, as depicted in Figure A2.7. For this reason, in such piggy-back configurations, the bonding conductor and the protective conductors must be sized to carry the maximum prospective fault current of the a.c. or d.c. system, whichever is the larger

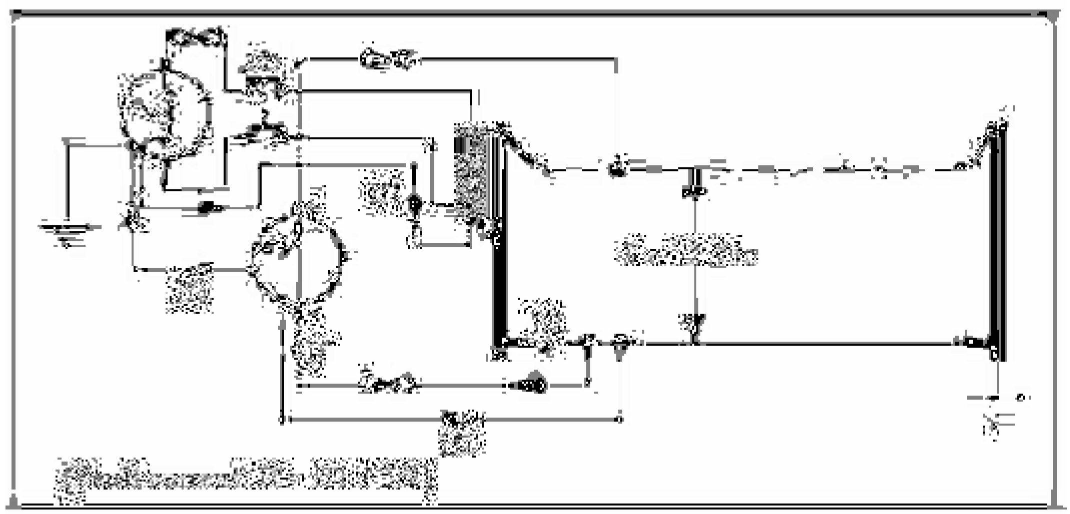

Figure A2.7 Dodgem supplied from d.c. generator with theme and other equipment supplied from 'piggy-back' a.c. generator, illustrating fault current flowing in the event of winding-to-frame fault on the d.c. set

Coin ejection mechanisms

28. Many dodgem rides have automatic token mechanisms in the cars. These incorporate a mechanical latching arrangement that maintains the token on a switch for the duration of the ride. The token is then ejected at the end of the ride, commonly by a momentary reversal of the polarity of the d.c. supply.

(a) From an electrical safety perspective, this facility does not present any additional hazards so long as the earthing and bonding arrangements are not affected by the temporary polarity reversal. Where this type of coin ejection technique is used, no other equipment should share the same d.c. supply as the dodgem track.

Appendix 3
Variations from EN 13814

1. The following text provides some explanation of supplementary safety provisions in Great Britain in addition to those contained in the European Standard EN 13814 - "Fairground and amusement park machinery and structures - safety".

2. The original proposals for revisions to the text of EN 13814, submitted by BSI in 2000, numbered approximately 128, of which about 57 were either adopted wholesale or dealt with in other ways in the final Standard dated December 2004. Unfortunately, there remain some serious issues. For instance, we believe there are cases of "requirements" which :-

(a) include matters which are not permitted in or consistent with other EN Standards;

(b) could be insufficiently safe, unsafe or dangerous; or

(c) break British or European law.

3. While we are pleased that the Standard has been published and that much of it is satisfactory, we have identified the following main points of objection which will necessitate additional or different safety measures to be followed for amusement devices that are to be used in Great Britain[27]

4. The Standard includes many references to types of inspection, approval, etc. which are inconsistent with current practice in Great Britain.

5. A consequence of the current state of the text is that compliance with the Standard would not necessarily be sufficient to satisfy British expectations. It is our view that designers etc. would need to fulfil additional conditions or variations imposed by ADIPS (the Amusement Device Inspection Procedures Scheme), the Health and Safety Executive's publication HSG 175, and this ADSC publication. Indeed, the amusement industry associations in Great Britain expect these to be followed. We consider that paragraphs numbered 3.2 - 3.7, 5.1.1, 5.1.4.2, 6.4.2.4.3.2, 6.4.2.4.3.3, 6.5, 6.6, 7 and Annex H may in some aspects conflict with or be insufficient to satisfy British expectations in this respect.

6. It has been British practice for over 20 years to expect that fatigue life assessments of components are to be carried out by designers. Unfortunately, EN 13814 does not require the designer to pass on any information regarding fatigue lives exceeding 35000 hours, nor to cross check that inspection / maintenance instructions are consistent with any of the calculated lives. We believe that this would be inconsistent with Section 6 of the Health and Safety at Work, etc., Act 1974. Indeed in relation to assessment of risks affecting workers (in contrast to the public), on which the European Union has common requirements, we believe that it would also break the law in the other member states.

7. For this and related reasons we consider that paragraphs numbered 5.6.1, 5.6.3 (including Table 6), 6.4.3.1.4 and Annex A may in some aspects conflict with British requirements, and duty holders would need to carry out fatigue life calculations for all safety-related components and, for each of those which are seen to have a life which is shorter than the maximum anticipated lifetime of the device, prepare maintenance and inspection schedules which are consistent with the results, including details of method and frequency that each procedure is to be carried out. Please note that there is a requirement in Great Britain for a written inspection / NDT schedule, often produced in tabular form for clarity, to be in place in the Operations Manual. Paragraphs 1 - 9 of Chapter 4 above are relevant.

8. Great Britain has recently introduced specific electromechanical safety advice for dodgems which covers some issues not addressed in EN 13814. We therefore consider that paragraph

[27] Note that if, as a duty holder, you follow the steps outlined here in addition to EN 13814 you will normally be doing enough to comply with British law. If you do otherwise you will need to demonstrate and justify equally effective compliance.

numbered 6.2.4.1.6 may in some aspects conflict with or fail to satisfy British expectations. Duty holders should refer to Appendix 2 above for more information.

9. EN 13814 now contains several references which tell the designer to apply partial safety factors for ultimate limit states even when carrying out fatigue life assessment. This is inconsistent with other Standards (e.g. EN 1993-1-9) and may result in underestimates of fatigue lives, onerous inspection regimes or, if re-design is carried out, unnecessarily heavy structures. We therefore consider that paragraphs numbered B.1.1, B.2.1 and B.3 may in some aspects conflict with British expectations. In accordance with British and European Standards covering fatigue (see, for instance, those listed in Chapter 4 above), input loads need not be factored when calculating fatigue lives and preparing associated inspection schedules.

10. Great Britain has recently updated and extended safety advice for amusement device electrical and control system design safety. We therefore consider that Annex D may in some aspects conflict with or fail to satisfy British expectations. Duty holders should refer to Chapters 9 and 12 above for more information.

11. British requirements for the assessment of design safety of passenger containment are more extensive than those in EN 13814. (For instance, there have been recent prosecutions of duty holders for not making proper use of anthropometric data in assessing safety). We therefore consider that 6.1.6 and Annex E (which is, in any case, only "informative") may in some aspects conflict with or fail to satisfy British requirements. Duty holders should refer to Chapters 9, 10 and 11 above for more information. These contain, amongst other things, anthropometric data associated with common passenger height limits. Such data, arranged by height, is not available in European or ISO Standards and is commonly miscalculated by designers.

12. It is also the British view that passenger reach distances, as required in the standard, do not take sufficient note of available anthropometric data and should be increased accordingly. The existing values will not prevent passenger's extremities from coming into contact with external objects (passenger clearance envelope)

13. Unlike earlier draft versions of EN 13814, there is no longer any reference to the need for design risk assessment to be carried out (formerly in a paragraph then numbered 6.1.3, immediately following 6.1.2, now deleted; see also Annex 1). Failure to do this assessment conflicts with British regulations. Indeed in relation to assessment of risks affecting workers (in contrast to the public), on which the European Union has common requirements, we believe that it would also fail to meet the law in the other member states. Design duty holders would need to ensure that a design risk assessment is carried out. This should form part of the package supplied to the ADIPS - registered inspection body responsible for its Design Review.

14. Paragraph 6.3.8.2.1.6 specifies safety factors for ropes and chains which are much smaller than those recommended by the Machinery Directive (98/37/EC). Although the Directive and related Regulations and ACOPs will not apply in many cases it may in some. Duty holders would need to consider whether to apply the larger safety factors.

15. In addition to these broad difficulties, we are aware of a number of specific details in EN 13814 (e.g. formulae) which we believe to be incorrect and which could lead to lack of safety. We identify the following :-

16. Wind loading (5.3.3.4.1) - British designers, inspection bodies, etc. are already expected to assess structural shape factors in accordance with BS 6399-2 and EN 1991-1-4. Figure 1 in EN 13814 is not consistent with either of these or with any other European or ISO Standard, so far as we can ascertain. Shape factors which accord with BS 6399-2 or EN 1991-1-4 should be used.

17. The third paragraph of 5.4.3.5 contains unsafe recommendations about when anti-rollback

devices may be dispensed with. Duty holders will need to assess whether the rollback of a roller coaster car or train through the station can be accomplished with minimal risk to passengers and others in the station area before omitting safety devices against running back.

18. The second paragraph of 5.7.3 does not deal with all the safety issues of which we are aware relating to open hooks. That is to say that, in the absence of other justification, the risk assessment should assume that in-service primary failure of a member having an open hook termination will lead to unhooking. The consequences of striking or spearing passers-by etc. should be considered.

19. Paragraph 6.1.4.5 does not deal adequately with all the known hazards associated with fences and railings having horizontal members. The following objectives should be satisfied where an associated unacceptable risk might result :-not permitting climbing (up, under or through); and not permitting trapped heads

20. Paragraph 6.1.6.1.7 no longer (compared with earlier drafts of the Standard) warns the designer about the risk of entrapment of body parts between the outside of the passenger containment and any object. Nor is there any mention of this in the subsection 6.1.6.1. It is our view that this will lead to a greater number of unsafe interpretations of the Standard and some non-compliance with Regulation 11 of the Provision and Use of Work Equipment Regulations 1998. Unguarded clearance distances in the Standard may be unacceptable for use in Great Britain where dangerous shear traps, etc., have not been removed. Duty holders should take account of Chapter 11 above or take other equally effective precautions to ensure compliance with British law.

21. Paragraphs A.4.2 and A.4.3 contain incorrect formulae numbered A.24 and A.31 which could result in unsafe results. Calculations involving these formulae will not be acceptable. Since the calculation of "equivalent constant amplitude stress range" is not a necessary step in the determination of fatigue life, we do not propose the use of any alternative formulae.

22. Annex G, which in any case is only an informative annex, has some remaining unresolved problems which could be unsafe. Duty holders should therefore be aware that compliance with this annex will not automatically imply that safety requirements have been satisfied.

23. For help in complying with British requirements, inspection bodies registered to carry out Design Review may be contacted.

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