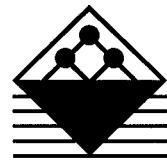


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**HEALTH & SAFETY
LABORATORY**

**Amusement Ride Controls and Operating
Procedures – Literature Review**

HSL/1998/01

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Summary

Objectives

- (i) To review published research papers relating to the design of amusement ride control panels and ride operating procedures.
- (ii) To review guidance on the design of amusement ride control panels and the operation of amusement ride.
- (iii) To identify existing standards which may be directly or indirectly related to the design of amusement ride control panels and ride operating procedures.

Main Findings

- (i) There appears to be a lack of information on control panel and operating procedure design which is directly aimed at the amusement industry.
- (ii) Current designs are dictated by a parks "house style" or individual whim.
- (iii) There are several sources of relevant information on control panel and operating procedure design including machinery standards which could be applied to the amusement industry.
- (iv) There is a need to determine the current state of control panel and operating procedure designs in the amusement industry to identify common errors.
- (v) There is a need to define the amusement ride operators task environment to identify the correct ergonomics principles to be applied.
- (vi) There is a need for guidance which helps amusement ride designers and operators identify the relevant sources of information and apply the ergonomics principles.
- (vii) There is a need for guidance which helps HSE inspectors to correctly identify problems during routine inspections and incident investigations.

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1. INTRODUCTION

It is not uncommon for incidents on amusement rides to be attributed to operator error, but how many of these are really human error and how many are actually a result of poor design? Many of the modern rides have complicated control systems with multilevel safety interlocks, computer control and varying levels of automation. The control panels, the interface between the operator and the ride, range from simple two or three button boxes to multi-panel consoles with visual display units (VDUs), a multitude of input devices and information displays. However, a control panel does not need to be complicated to induce human error. Selection of the wrong type of button can lead to the wrong one being pressed in an emergency situation eg. using a large, red, mushroom head button which locks in (sometimes labelled STOP) to start the ride. Panels may be too simple; a lack of information feedback may lead to a dangerous situation going undetected. It is not only the design of the panels which may be at fault, a poorly structured operating procedure may increase the likelihood of human error. A poor operating procedure may work against a well designed control panel or may be the result of coping with a badly designed control panel.

Displays and controls ergonomics is not a new concept and many of the basic principles appear in text books. These principles have been incorporated in Standards also. Human error reduction and the design of operating procedures is well documented too. How much of this information is readily available to designers of amusement rides and their associated control systems? This report will attempt to identify what relevant information is available and how accessible it is to the amusement industry.

2. ERGONOMICS TEXTS

2.1 Displays & controls

Ergonomics principles for the design of control panels can be found in most general ergonomics texts. Applied ergonomics handbook (Galer, 1987) has chapters on the design of displays, the design of controls and the layout of panels and machines. Principles such as information flow loops, control / display relationships, functional grouping, link analysis and systems ergonomics are also discussed. Other sources of information on these topics are Fitting the task to the man (Grandjean, 1981), Human factors in engineering and design (McCormick & Sanders, 1982). Although some practical examples are given, much of the information is presented for ergonomists.

2.2 Automation

Parasuraman & Riley (1997) discusses the use, misuse, disuse and abuse of automated systems. In their introduction they state "A prevalent assumption about automation is that it resides in tyrannical machines that replace humans, a view made popular by Chaplin in his movie Modern Times. However, it has become evident that automation does not supplant human activity; rather, it changes the nature of the work that humans do, often in ways unintended and unanticipated by the designers of automation." They go on to define automation as "the execution by a machine agent (usually a computer) of a function that was

previously carried out by a human." However, automation does not always completely replace the human, Sheridan (1980) identified 10 levels of automation.

It is often considered that the introduction of automation will reduce the chance of human error by reducing the operators workload or taking him out of the system altogether. In systems where the human is retained as a component, there are several factors which affect how they interact with the automated functions. Muir (1988) argued that individuals trust for machines can be affected by the same factors that influence trust between individuals. People trust others if they are reliable and honest but they lose trust when they are let down or betrayed and the subsequent redevelopment of trust takes some time. In her experiments, she found that a subjective measure of trust in an automated aid correlated with its usage by the subjects. In the worst cases a lack of trust of the automated system may result in the operator bypassing or disabling the automation. Conversely, excessive trust can lead operators to rely uncritically on automation without recognising its limitations, or fail to monitor the automations behaviour. It has also been pointed out that reliance on the decisions of automation can make humans less attentive to contradictory sources of evidence : Mosier & Skitka (1996).

There is a temptation to use automated systems to remove human error but without a clear understanding of the human factors associated with the use of automated systems one could simply replace operator error with designer error.

2.3 Operating procedures & human error reduction

The basic techniques which underlie the design of operating procedures and human error reduction use some form of task analysis. Task analysis can be defined as the study of what an operator (or team of operators) is required to do, in terms of actions and / or cognitive processes, to achieve a system goal (Kirwan & Ainsworth, 1992). There are many task analysis techniques, Kirwan & Ainsworth list 25, some of which may be used directly in the assessment of amusement ride control and operating procedures.

Human Reliability Assessment (HRA) techniques are used to predict human performance in high risk industries. Their aim is to determine the risks inherent in such industries due to human error and the benefits in terms of risk reduction by having human operators in the system. Kirwan (1996) published a series of three papers which reviewed the validity of three HRA techniques. The papers concentrated on the prediction of Human Error Probabilities (HEP). HEP estimation may be a useful technique in designing the more complex amusement ride control systems but there are some problems. HRA techniques generally use either information in a database of industrial incidents with expert judgement or they may rely solely on expert opinion. One aspect shared by most HRA techniques is that they start with a detailed task analysis. As discussed above, task analysis could be a very valuable tool in the design of control panels and operating procedures on amusement rides. However, extending this to full HRA may be inappropriate as most of the techniques have been developed for highly complex systems such as those found in nuclear processing plants and large chemical installations. As such the majority of database information and expert opinion is focused in these areas. There are some principles used in HRA which may be adapted for the design of amusement ride control systems and operating procedures such as

Performance Shaping Factors (PSF). In HRA, PSF are used to support modification of the basic error probability in quantitative analysis. In the absence of basic quantitative data for HRA in the amusement industry, PSF may be used in qualitative assessment of a particular design. Some of the common factors are: Man machine interface / feedback; procedures; training; time pressure, stress or workload, teamwork problems.

3. STANDARDS

There are a few countries who have standards for amusement rides. Australia has a standard AS 3533-1988 "Amusement rides and devices" and specific references to amusement rides in regulations as diverse as construction regulations and lifting equipment regulations. In Europe the longest established standard is DIN4112 in Germany. There is no British standard for amusement devices. Work is in progress on a European standard for amusement devices but there is no European Directive associated with it. The machinery directive specifically excludes amusement rides although it does address some relevant ergonomics principles. A result of the inclusion of ergonomics principles in European Directives are Standards which now directly address ergonomics design, most notably the series on safety of machinery.

BS EN 894-1:1997 "Safety of machinery - Ergonomics requirements for the design of display and control actuators, Part 1. general principles for human interactions with displays and control actuators" sets out many of the basic ergonomics principles with examples of their application. Although not directly addressing amusement ride designs, the principles are directly applicable. The standard states that "Knowledge of ergonomics principles is the basis for a successful implementation of a human - machine system." The systems approach is adopted as it is recognised that "an important factor to consider is the degree to which the human is needed in the system in order to accomplish the given task." Some of the principles included in the standard are: Principle of function allocation - should it be done by man or machine? Principle of grouping - locating related displays and controls in the same area. Principle of information availability - information about the status of the system should be readily available at the request of the operator without the need to interfere with other activities. Conformity with user expectations - population stereotypes and other user expectations of how the human - machine interface operates. Principle of consistency - Similar parts of the human - machine interface should operate in a consistent manner. Other principles are presented along with information on human information processing.

BS EN 894-2:1997 "Safety of machinery - Ergonomics requirements for the design of display and control actuators, Part 2. Displays" not only covers visual displays but includes ergonomics guidance on auditory and tactile displays also. The comprehensive yet concise data in the standard would assist greatly in the design of displays.

BS EN 61310-1:1995 IEC 1310-1:1995 "Safety of machinery - Indication, marking and actuation, Part 1. requirements for visual, auditory and tactile signals" specifies a system of colours, safety signs, markings and other warnings, intended for use for the indication of hazardous situations, and health hazards and for meeting certain emergencies. It also specifies ways of coding visual, auditory and tactile signals for indicating and actuating

devices in order to facilitate the safe use and monitoring of the machinery. It acknowledges that safety related information should be presented using means which are compatible with the capabilities of the operators and / or exposed persons. BS EN 61310-2:1995 IEC 1310-2:1995 "Safety of machinery - Indication, marking and actuation, Part 2. requirements for marking" states that "machinery shall bear all markings which are unnecessary for its unambiguous identification and for its safe use. Markings related to mechanical hazards, fluid power hazards and electrical hazards are dealt with. An important issue, which is directly relevant to amusement rides, is that textural information should be in the language(s) of the country in which the machine is to be used and may be, at the users request, in the language(s) understood by the operators and exposed persons. It is common for foreign rides to tour the UK with signage in their native language.

To help designers in the reduction of risks associated with misinterpretation of visual and auditory danger signals, BS EN 981:1997 "Safety of machinery - System of auditory and visual danger and information signals" specifies a system for signals which takes into account the different degrees of urgency. The standard contains tables which set out the message categories, types of signal and their associated meanings. Such standardisation of signals would avoid confusion of meaning for operators and public regardless of which ride or park they were on.

Further guidance on signals can be found in BS EN 842:1996 "Safety of machinery - Visual danger signals - General requirements, design and testing." This standard appears to be less detailed than some of the others but it is still a good basic guide.

Guidance specific to auditory signals is given in BS EN 457:1992 "Safety of machinery - Auditory danger signals - General requirements, design and testing." However, this standard does not apply to verbal danger warnings eg. shouts, loudspeaker announcements. The section on test methods contains a lot of technical detail relating to acoustic measurements and the calculation of effective masked threshold. The annex to this standard contains worked examples of the applied design principles.

Almost all amusement ride control systems will include an emergency stop function. BS EN 418:1992 "Safety of machinery. Emergency stop equipment, functional aspects - Principles for design" gives guidance which could be used to standardise the appearance and the function of emergency stop controls on all rides in all locations. Under general requirements it is stated that "the emergency stop function shall be available and operational at all times, regardless of the operating mode." An important issue covered is that "the emergency stop equipment shall neither be used as an alternative to proper safeguarding measures nor as an alternative for automatic safety devices, but it may be used as a backup measure." This suggests that the human operator should not be allocated the emergency stop function as a matter of course but they should have the option to invoke the emergency stop function as a backup to the automated system. This raises some of the issues discussed in the section on automation. However, some allowance for human intervention is made as it is stated that "resetting the control device shall not by itself cause a restart command." Standardisation of the appearance of the emergency stop actuator is dealt with in the section on shape, colour and arrangement of emergency stop actuators. Although several alternatives for the actuators are given, the standard is very precise about the colour of such actuators. "The emergency

stop actuators shall be coloured red. As far as a background exists behind the actuator and as far as it is practicable, it shall be coloured yellow."

4. HSE PUBLICATIONS

4.1 Guidance notes

The main guidance for fairgrounds and amusement parks has recently undergone a major revision and has been published as HSG175, Fairgrounds and Amusement Parks Guidance on safe practice (1997). The guidance for designers states that: "Any limitations for safe operation need to be specified in the operations manual." This information is essential when designing safe operating procedures. In discussing design review, the guidance warns of incompleteness and gives the examples "no attention to control systems or passenger containment systems" and false assumptions such as "a software control system will fail safe." Appendix 2 of the guidance suggests some "principles of designing for safety" but these are mechanical solutions which do not consider the human inputs and outputs in a control system. The guidance identifies control systems as an essential part of the annual thorough examination with functional testing of all safety critical inputs and outputs but does not specifically say whether the inputs and outputs are from a machine or human. Daily checks on a ride are listed as one of the responsibilities of the ride controller. One of the daily checks listed is a trial run to check that safety controls, including communication systems operate effectively. Again it is neither stated nor implied that the human is to be checked as a component in the system. The sections on "safe operation by operators" and "supervision by attendants" address some human factors issues but in a very general and sometimes vague manner. The list of "useful reading" material at the end of the guide does not contain any ergonomics texts. The only ergonomics reference is the "Thrills Not Spills" video produced by HSE which is "a guide to the ergonomics of passenger containment."

HSE also publish 12 guidance notes in the plant and machinery series titled "safe operation of passenger carrying amusement devices." The full list is given in the reference section of this report. The information given in these guidance notes on the safe operation of the particular ride to which the note applies varies from ride to ride. However, there are a few common points raised such as: A safe system of work should be instituted by ride operators and attendants; the operator should determine the number of attendants required to operate the ride safely; operators and attendants should receive suitable training. Details are given of particular risks associated with particular rides.

4.2 Information Sheets

To supplement their guidance notes, HSE publish free information sheets. One example is NIS/18/02 "Safe access to juvenile chair-o-planes and Similar rides". This sheet touches on operating procedures as it discusses the level of supervision by ride operators and attendants. However, no information sheets were found which directly address control panel and operating procedure design. The information sheets tend to tackle even more specific issues than the guidance notes.

4.3 Video

HSE produced the "Thrills Not Spills" video which is a guide to the ergonomics of passenger containment. Although safe containment of passengers is an important consideration in the operation of amusement rides, the video does not directly address operating procedures.

5. INTERNET

The amount of information available on the internet is overwhelming and one can spend a lot of time sorting the relevant information from the irrelevant. However, selective searches produced a list of 43 amusement industry companies and organisations (http://users.sgi.net/~rollocst/a_ind.html) with links to their web pages. One of those listed was Birket Engineering Inc. (<http://www.birket.com/>) who manufacture ride control systems. On their web site they publish technical notes relating to control systems and their components.

In technical note "Concerning Frequency of Operation in Interlock Design" (<http://www.birket.com/technotes/interlocks.html>) it is stated that "Interlocks are designed into a system as a degree of protection against harm resulting from events such as equipment failure, human error and unusual circumstances." Birket recognise that interlocks only offer a degree of protection as in the same note they say "Interlocks are never a substitute for operator training or an intrinsically safe design." They also raise the issue of bypassing interlocks and suggest that frequency of operation, cycling and pre-operation test procedures need to be considered in control system design in order to cope with such negative human intervention. They take this concept further in technical note "Safety Interlocks Not Always a Good Idea" (<http://www.birket.com/technotes/nointerlocks.html>) by suggesting that human reliance on interlocks or a misunderstanding of what function an interlock serves by the operator can encourage human behaviour which ultimately leads to an incident attributed to human error. Interlocks should not replace safety procedures and operator training. In a purely engineering approach, the situation where interlocks are protected by interlocks can arise. A combination of engineering and ergonomics can lead to a safer and more productive system design. As Birket are an American company they are overtly aware of company liability issues and suggest that there is a tendency to liability-proof machines with warning labels. However, they also suggest that one can not depend upon people to read labels and even if they do, it may lead to an overload of information and warnings that are not followed.

Birket Engineering were contacted by E-Mail to get their view on the current industry practices in control panel design. Their reply stated that larger parks determined or greatly influenced the layout of control panels whilst smaller parks left it all up to the supplier. As for standardisation of displays and controls layout and design, in the USA, the standards vary from one family of parks to another with Disney being seen as the leaders. Asian customers tend to accept whatever the Americans use. Birket have not done much work in Europe but they seem to think that TUV influence the way things are done. As for the components used in their designs, operator functions are dealt with using physical switches and illuminated indicators whilst Maintenance functions use a graphical touch screen or Windows based PC.

6. DISCUSSION

Much of the ergonomics information required to design effective amusement ride control panels and operating procedures is readily available in some form. Very little, if any, information is aimed directly at the amusement industry or anyone who is not already aware of the ergonomics issues. The ergonomics text books serve as a good reference for those with ergonomics training. It would be unreasonable to consider these as a ready made guide for designers, manufacturers and operators of amusement rides. The history of standards in the amusement industry has resulted in an ad hoc voluntary system. Amusement devices are specifically excluded from the European machinery directive although many of the machinery standards address the same ergonomics issues, as detailed above, and may be directly applied to amusement devices. However, the politics are such that ride designers, manufacturers and operators are unlikely to turn to these standards. However, the Health and Safety Executive continues to encourage the fairgrounds industry, where appropriate and practicable, to adopt principles and practices of European Standards produced under the Machinery directive.

A common issue raised in most of the texts and standards is that the context in which the ergonomics principles and techniques are to be applied needs to be defined. Suitably detailed definitions of the amusement ride operators task environment do not appear to exist. This can be overcome by using standard task analysis techniques which are well documented. It would also be useful to determine the current state of amusement ride control panel designs and operating procedures in order to identify common errors. Again, many standard ergonomics techniques are readily available and well documented to achieve this. Once this information was available, it would be possible to identify existing information which could be used to solve existing problems and aid future designs and identify the areas where information may be lacking. It would be unproductive to duplicate information which already exists elsewhere and so any guidance for the amusement industry should identify existing sources and then show how they can be applied to the industry. The current HSE guidance does not directly address these issues. It does provide for functional testing of control systems in the annual thorough examination but does not specifically mention human functions. The thorough examination is the amusement ride equivalent of the car MOT test so it is questionable if the human input should be part of this test as the car driver is not tested in the MOT. It is suggested that further HSE guidance needs to be provided on the ergonomics issues associated with ride control panel design and operating procedures. Not only would this help the industry to get it right at the design stage ie. before it goes wrong, it would also help HSE inspectors to correctly diagnose the problems when things have gone wrong.

7. CONCLUSIONS

- (i) There appears to be a lack of information on control panel and operating procedure design which is directly aimed at the amusement industry.
- (ii) Current designs are dictated by a parks "house style" or individual whim.

- (iii) There are several sources of relevant information on control panel and operating procedure design including machinery standards which could be applied to the amusement industry.
- (iv) There is a need to determine the current state of control panel and operating procedure designs in the amusement industry to identify common errors.
- (v) There is a need to define the amusement ride operators task environment to identify the correct ergonomics principles to be applied.
- (vi) There is a need for guidance which helps amusement ride designers and operators identify the relevant sources of information and apply the ergonomics principles.
- (vii) There is a need for guidance which helps HSE inspectors to correctly identify problems during routine inspections and incident investigations.

8. REFERENCES

BS EN 418:1992 "Safety of machinery. Emergency stop equipment, functional aspects - Principles for design"

BS EN 457:1992 "Safety of machinery - Auditory danger signals - General requirements, design and testing."

BS EN 842:1996 "Safety of machinery - Visual danger signals - General requirements, design and testing."

BS EN 894-1:1997 "Safety of machinery - Ergonomics requirements for the design of display and control actuators, Part 1. general principles for human interactions with displays and control actuators"

BS EN 894-2:1997 "Safety of machinery - Ergonomics requirements for the design of display and control actuators, Part 2. Displays"

BS EN 981:1997 "Safety of machinery - System of auditory and visual danger and information signals"

BS EN 61310-1:1995 IEC 1310-1:1995 "Safety of machinery - Indication, marking and actuation, Part 1. requirements for visual, auditory and tactile signals"

BS EN 61310-2:1995 IEC 1310-2:1995 "Safety of machinery - Indication, marking and actuation, Part 2. requirements for marking"

DIN 4112 "Temporary structures- Code of practice for design and construction"

- Galer, I. (1987) Applied ergonomics handbook, Butterworths, UK
- Grandjean, E. (1981) Fitting the task to the man, Taylor & Francis, UK
- HSG175, Fairgrounds and Amusement Parks Guidance on safe practice (1997), HSE
- Kirwan, B., Ainsworth, L. K. (1992) A guide to task analysis, Taylor & Francis, UK
- McCormick, E.J., Sanders, M.S. (1982) Human factors in engineering design, McGraw-Hill, USA
- Mosier, K., Skitka, L.J. (1996) Human decision makers and automated decision aids: Made for each other? in Automation and human performance: Theory and applications (pp. 201 - 220). Hillsdale NJ. Erlbaum.
- Muir, B.M. (1988) Trust between humans and machines, and the design of decision aids. in Cognitive engineering in complex dynamic worlds (pp 71 - 83). London : Academic.
- NIS/18/02 "Safe access to juvenile chair-o-planes and Similar rides", HSE.
- Parasuraman, R., Riley, V., (1997) Humans and automation: use, misuse, disuse, abuse. Human factors 39(2), 230 - 253. USA.
- PM 47, 1985, Safe operation of passenger carrying amusement devices: The Waltzer, HSE
- PM 48, 1985, Safe operation of passenger carrying amusement devices: The Octopus, HSE
- PM 49, 1985, Safe operation of passenger carrying amusement devices: The Cyclone Twist, HSE
- PM 57, 1986, Safe operation of passenger carrying amusement devices: The Big Wheel, HSE
- PM 59, 1986, Safe operation of passenger carrying amusement devices: The Paratrooper, HSE
- PM 61, 1986, Safe operation of passenger carrying amusement devices: The Chair-O-Plane, HSE
- PM 68, 1987, Safe operation of passenger carrying amusement devices: The Roller Coaster, HSE
- PM 70, 1988, Safe operation of passenger carrying amusement devices: The Ark / Speedways, HSE
- PM 71, 1989, Safe operation of passenger carrying amusement devices: The Water Chute, HSE

PM 72, 1990, Safe operation of passenger carrying amusement devices: The Trabant, HSE

PM 76, 1991, Safe operation of passenger carrying amusement devices: Inflatable bouncing devices, HSE

PM 78, 1994, Passenger carrying aerial ropeways, HSE

Sheridan, T. (1980) Computer control and human alienation. *Technology review*, 10, 61 - 73.

Thrills Not Spills (video), HSE, CFL Vision, UK

http://users.sgi.net/~10llocst/a_ind.html Amusement industry companies and organisations.

<http://www.birket.com/> Birket Engineering Inc.

<http://www.birket.com/technotes/interlocks.html> Concerning Frequency of Operation in Interlock Design

<http://www.birket.com/technotes/nointerlocks.html> Safety Interlocks Not Always a Good Idea