AMUSEMENTS PARKS:
CASE STUDIES
&
SAFETY AUDITS

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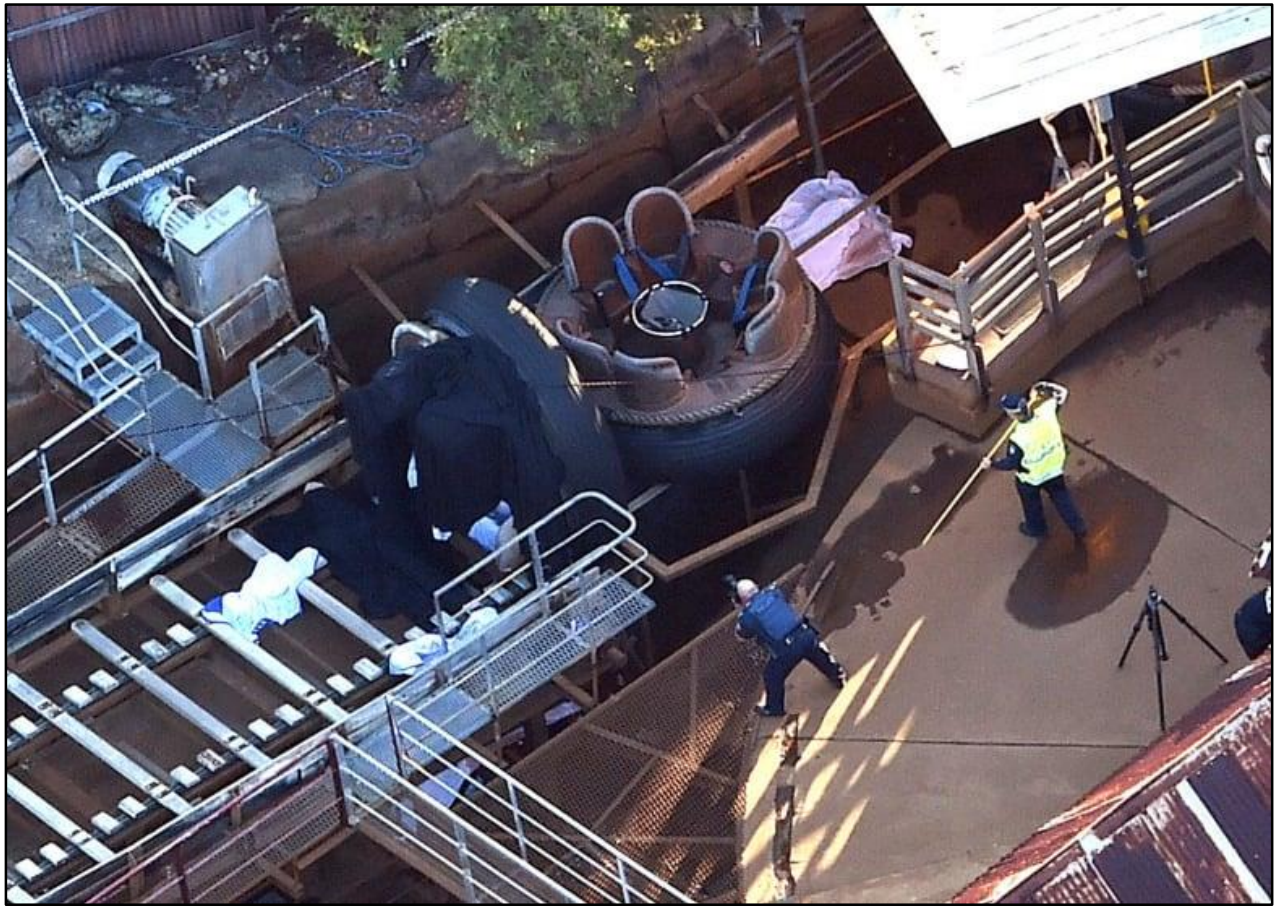
Topics

- **Major Accidents & Mishaps in Amusement Parks**
- **Case Study**
- **Importance of Safety Audits**

Accidents & Mishaps



- **Dreamworld, Australia, Thunder River Rapids, Oct 2016:**
  4 guests killed when a raft flipped over. Ride permanently closed

Accidents & Mishaps

- **Kings Clown Ride, Nebraska, US, May 2016: 11 year old girl gets scalp torn off due to hair entanglement**

Accidents & Mishaps

- **Expoland, Fujin Raijin II Roller Coaster, Osaka Japan, May 2007: Broken wheel axle caused derailment and one guest died from head injuries.**

Accidents & Mishaps

- **Expoland, Fujin Raijin II Roller Coater, Osaka Japan, May 2007:**
- **The park which had operated successfully for 37 years before the accident had to shut down**

Accidents & Mishaps

- **Tsunami Roller Coaster, M&D's, Scotland, June 2016:**
  5 gondolas of the inverted roller coaster crashed 30 ft. 9 injured.
  Weld repairs on axle found faulty. Welding metal & axle metal incompatible. Ride closed permanently

Accidents & Mishaps

- Accidents closer home
  - Vertical Axle Pin Failure on Roller Coaster
  - Tower Drop Wire Rope Failure accident
  - Safety Harness Failure
  - Hair entanglement in go-kart ride
  - Pendulum ride shaft failure

Accidents & Mishaps

- **Typical Causal Factors of Accidents in Amusement Parks**
  - **Rider Restraint Systems Failure: Patrons getting ejected from seats**
  - **Control Systems Failure: Cars / Gondolas colliding**
  - **Electrical System Failure: Electrocution / Electrical fires**
  - **Structural Ride Components: Metal fatigue leading to component failures**
  - **Hydraulic failures: Uncontrolled seizure of ride**
  - **Emergency Response Plan: Rescue of patrons at height hampered**
  - **Crowd Management: Stampede**
  - **Security Measures**

Case Study

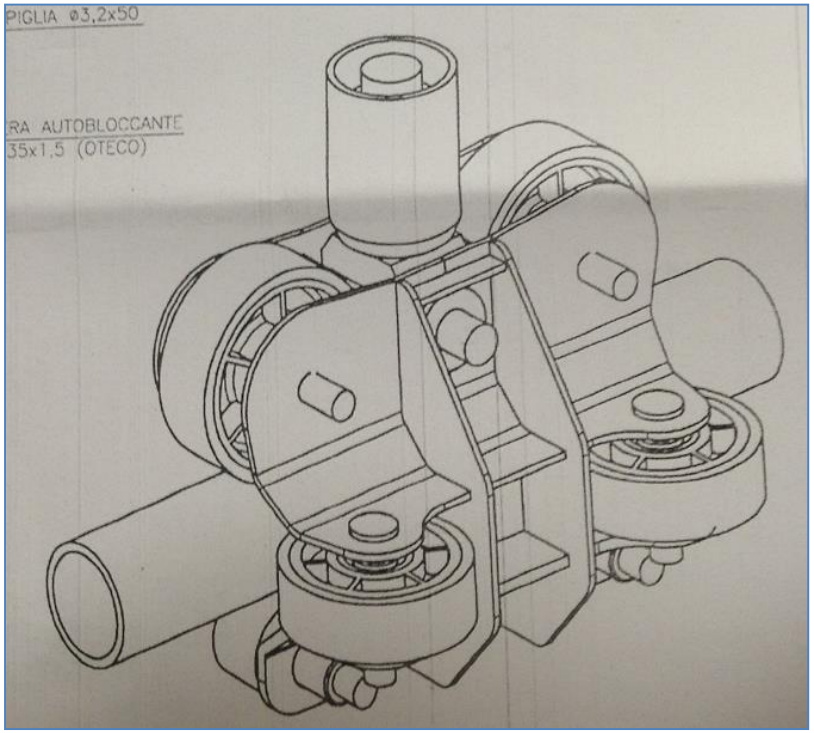
Roller Coaster - Vertical Axle Pin Failure Investigation

Case Study

- Accident occurred in Feb 2014
- The mini roller coaster stalled in its track as the last 2 bogies slipped from the track
- Left side pins of the wheel equaliser of the last 2 bogies in the train failed one after the other
- Non-fatal injuries to guests
- Mec Elec was invited to investigate

Case Study

- **Vertical axle** is critical part of a roller coaster as it connects the car to the wheel equaliser assembly
- It is a forged part with two taper bearings mounted on induction hardened surface
- Axle is subjected to **shear load in the linear** and **perpendicular direction** and some fatigue and bending loads

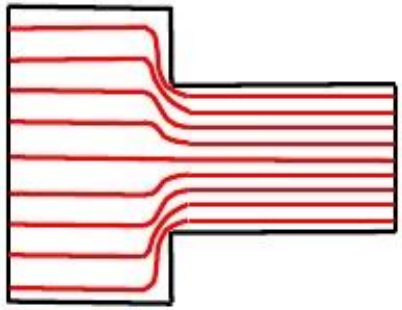


Case Study

- **Axle pin had a few steps / shoulders that could have acted as stress concentrators if not properly rounded**

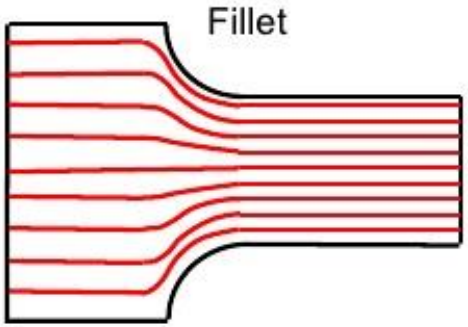
Case Study

Stress Concentration



Abrupt change

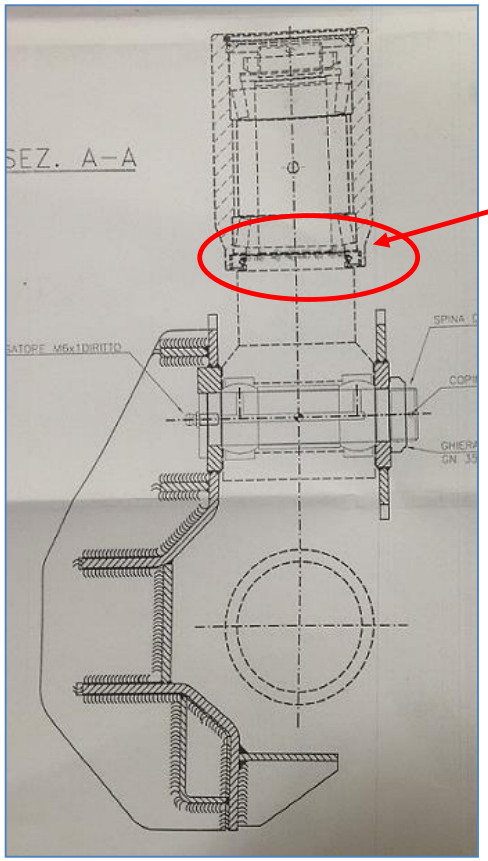
Stress “flow lines” crowd together causing high stress concentration in transition zone



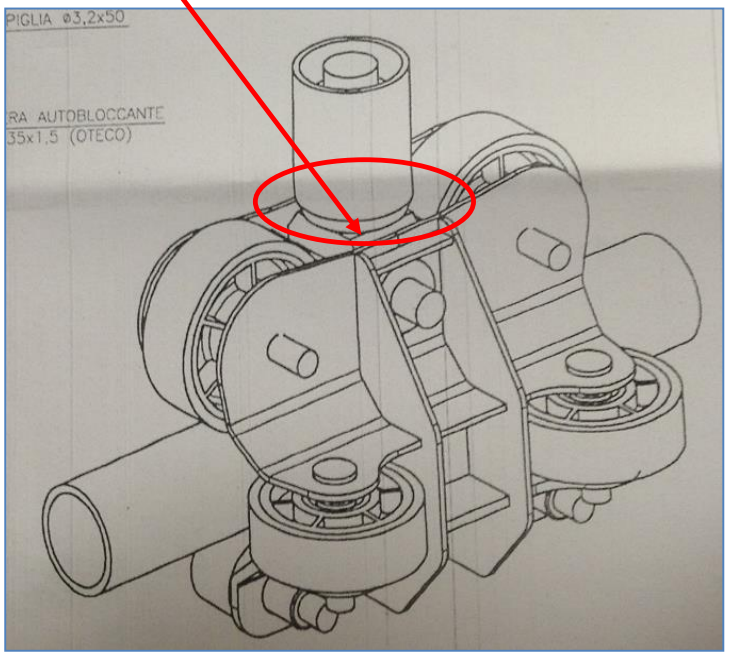
Smooth change

“Flow lines” more evenly distributed causing lower stress concentration in transition zone

Case Study

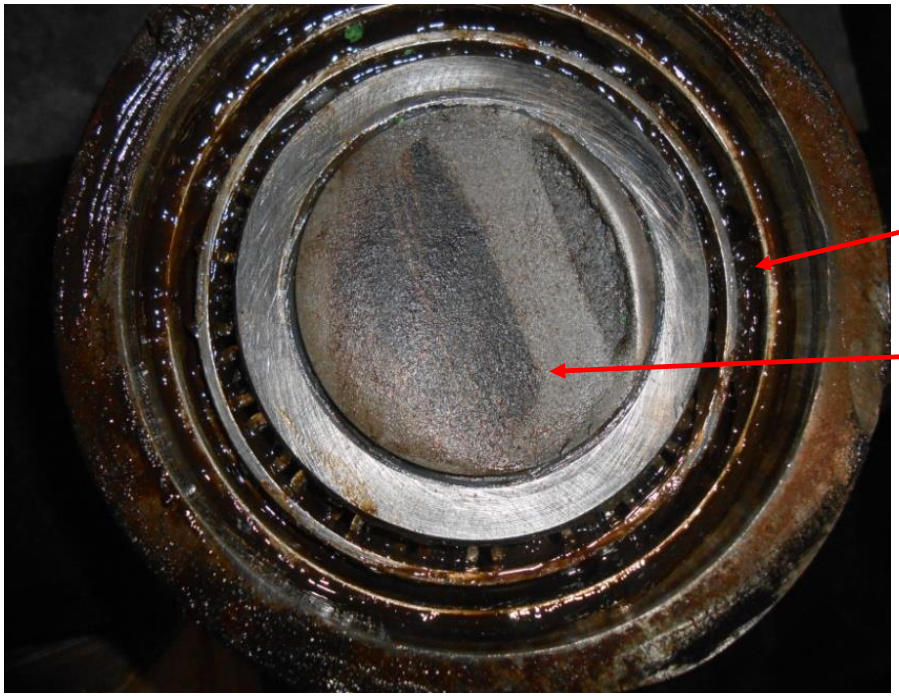


Location of Axle Failure of both cars – 6 & 5



- **Location of plane along which axle failure occurred in car number 6th and 5th car**

Case Study



Taper bearing (intact). Failure occurred just below the taper bearing

Sheared section of axle

- **The shaft snapped exactly at the location of the shoulder / step**

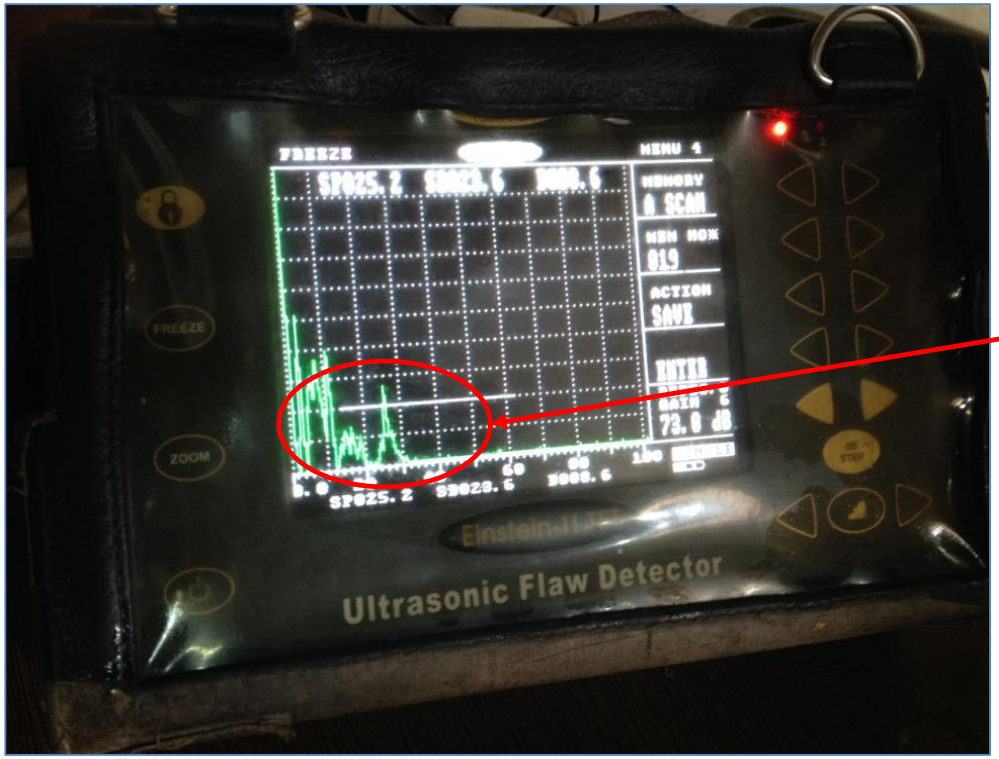
Case Study

- **Location of failure of the axle was inside its assembly housing and was not readily accessible either for visual inspection or for NDT**
- **The ride had completed only 20% of its expected one year design run**
- **The manufacturer's recommended inspection of the vertical shaft by stripping open the car was still a few months away**
- **NDT of the undamaged vertical shaft in Car number 4 was conducted**
  - **UFD - Ultrasonic Flaw Detection**
  - **MPI - Magnetic Particle Inspection**
  - **LPT - Liquid Penetrant Testing**

Case Study

- **UFD carried out to identify subsurface cracks, voids, porosities**

Case Study



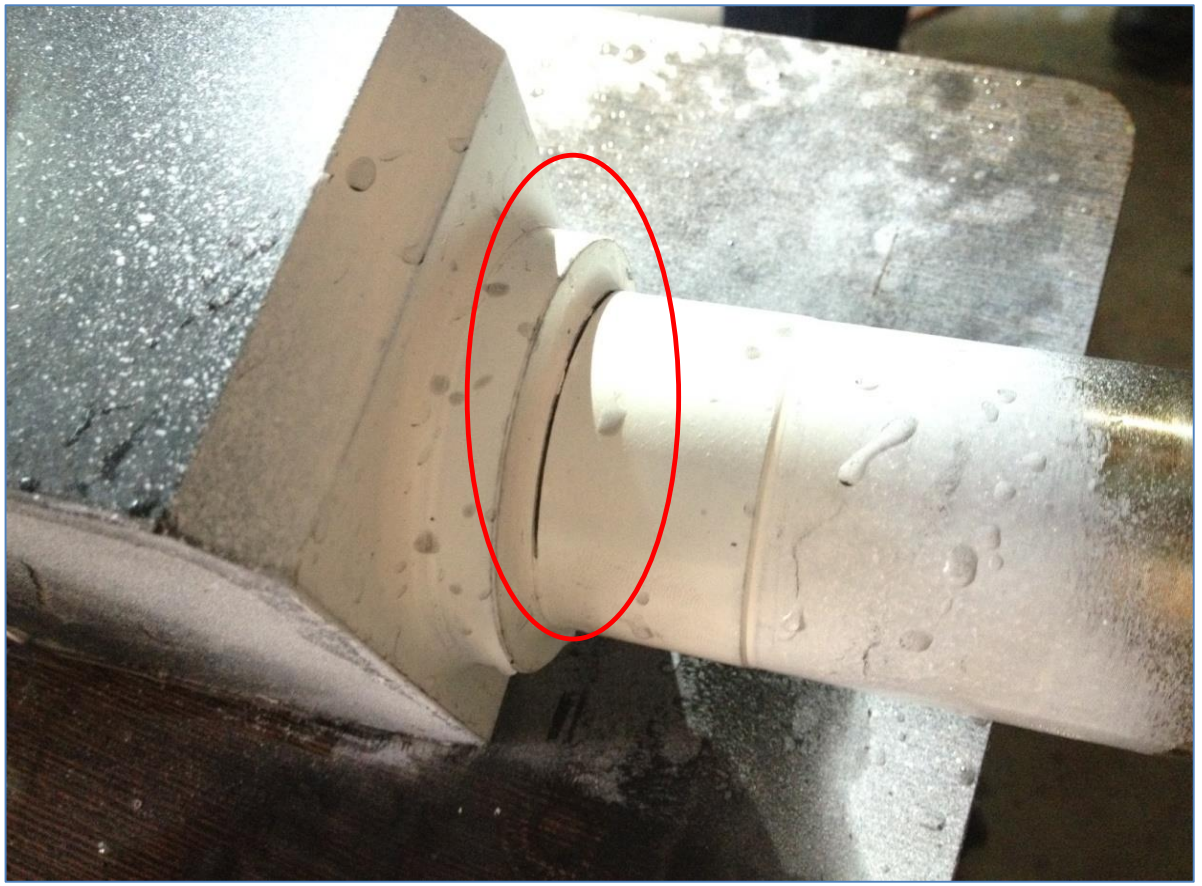
Relevant indication near axle shoulder

- **UFD indicated surface discontinuities**

Case Study

- **MPI is used to detect surface and subsurface cracks**

Case Study



- **MPI displayed a sharp indication near the shoulder**

Case Study

- **Final confirmation with LPT to detect surface cracks**

Case Study

- Manufacturing of critical mechanical equipment involves stringent internal and third party inspection
- Internal Inspection reports from the manufacturer were sought
- Reports did not indicate any third party inspection or NDT during the manufacturing

Case Study

- Industry associations release periodic Safety Alerts
- Further investigation of similar incidents associated with the vertical axle pin failure has revealed that there had been at least three notifications by NAFLIC highlighting similar design issues with other ride manufacturers

Case Study

Dec 1997 – Tech. Bulletin 160

Fatigue cracking has occurred at a shoulder of the main vertical pivot pin of several rear axles. The fact that several different such cracks have been found implies that this may be a shortcoming of the design detail and not just a simple manufacturing fault. All rides of this type are

Sep 1999 – Tech. Bulletin 191

The photographs of the axle show a classic bending fatigue failure initiating from a very small, but sharp shoulder. Ultrasonic testing of 18 of these shoulders has indicated 4 more cracks and a possible 3 in the early stages of propagation. In most cases these axles are approxi-

Oct 1999 – Tech. Bulletin 196

The axle fatigue failure which caused the crash occurred at a shoulder of the main vertical axle pivot pin. The partial fatigue damage to the other broken axles was clearly visible. From the information we have received it is clear that the shoulder cannot be examined, either visually or by NDT, without strip down. A second crack location exists at the weld attaching the pivot

Case Study

- It was concluded that the failed and cracked vertical axles were
  - a product of either inadequate design considerations
  - or improper inspections and process control at the manufacturing stage
  - or both.
- The axles were not due for NDT inspection (possible only after a complete strip down of the cars) for at least a few more months. The operations too were only about 20% of the expected running time for a year of service.
- The O&M personnel were entirely compliant with inspection guidelines and schedule of the manufacturer

Safety Audits

- In Safety Audits, we look beyond the immediate causes of an incident
- It is far too easy and often misleading, to conclude that carelessness or failure to follow a procedure alone was the cause of an incident.
- Safety audit helps to discover the underlying or root causes of the incident and therefore to identify the systemic changes and measures needed to prevent future incidents

Safety Audits

- **Policies & Procedures of a company demonstrates the Owner's intention to prevent injury, illness and property damage by providing necessary resources to eliminate accident / incident**

- **Safety Audit leads to identification of items that may need to be added to any checklist for future reference.**

Safety Audits

- **Safety Audit / Inspection Visits are important means of Identifying HAZARDS**
- **Safety Audit helps in bringing about improvements in Occupational Health & Safety at the Workplace.**
- **Safety Audit aids in developing safe work practices / procedures and in the education / training of all concerned.**

Safety Audit Standards

Designation	Description
ASTM F 2974	Standard Practice for Auditing Amusement Rides and Devices
ASTM F 770	Standard Practice for Ownership. Operation, Maintenance and Inspection of Amusement Rides and Devices
ASTM F1193	Standard Practice for Quality, Manufacture and Construction of Amusement Rides and Devices
IS:15475-2	Code of Recommended Practice for Amusement Rides-Safety Requirements
IS:15475-4	Code of Recommended Practice for Amusement Rides-Safety Requirements –Selection, Training and Supervision of Operators
IS:15492	Code of Recommended Practice for Safety in Water Parks
	BEST INDUSTRY PRACTICES

Safety Audit Elements

- **Review of Documents**
  - ✓ **Conformance to Manufacturer's Recommendations**
  - ✓ **Operations**
  - ✓ **Preventive Maintenance (Mechanical & Electrical)**
  - ✓ **Pre- Opening Checks**
  - ✓ **Inspection & Testing including NDT**
  - ✓ **Training**
  - ✓ **Medical**
  - ✓ **Fire**
  - ✓ **Emergency / Evacuation Plan**
  - ✓ **Management of Change**

Safety Audit Elements

- Guest Safety
- Housekeeping
- Field Visit-Visual Inspection of the Rides
- Communication
- Signages

Safety Audit Elements

- Instructions, Restrictions and Warnings
- Ride Experience
- Feedback from Patrons
- Statutory Compliance
- Facilities for Patrons & their Maintenance

Safety Audit - Water Parks

- Filtration & Water Purification Process
- Water Quality
- Plumbing
- PPE
- Rescue Personnel-Training & preparedness

What the Auditors Look For

- Seat Interlocks
- Malfunction of Restraint System
- Damaged Seat Belts / Lap Bars
- Corrosion of Ride Components.
- Corrosion / Damage to the Structure
- Leakages
- Railings/ Platforms
- Safety of Patrons & Operating staff

What the Auditors Look For

- Preventive Maintenance Procedures
- Fault reporting and remedial action
- Root Cause Analysis of Breakdown / Failures
- Inspection Methods
- NDT
- Shutdown Planning

What the Auditors Look For

- Shutdown Planning
- Signages & Warnings
- Instructions to the Patrons
- Ride Experience
- Feed back from Patrons
- Housekeeping

What the Auditors Look For

- Emergency response Plan
- Statutory Compliance
- Electrical Safety
- Earth Circuit and its Maintenance
- Hazard Identification & Risk Assessment of the rides
- Use of PPE
- Fire Safety

What the Auditors Look For

- Water Quality
- Water Filtration & Test Procedures
- Specific Hazards in Water Rides
- Lifeguards and their duties
- Medical Facilities
- Accident Reporting
- Analysis of Injuries and Corrective actions

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Thank You