Statens haverikommission

Accident involving the rollercoaster Jetline at Gröna Lund

The Swedish Accident Investigation Authority has investigated an accident at Gröna Lund in Stockholm on 25 June 2023.

14 June 2024

Final report

SHK 2024:07

Information about the Swedish Accident Investigation Authority

The Swedish Accident Investigation Authority (SHK) investigates accidents and serious incidents from a safety perspective, regardless of whether they took place on land, at sea or in the air. SHK's accident investigations shall disseminate knowledge and provide evidence that authorities, companies, organisations and individuals can use to implement measures to improve safety and reduce the risk of accidents. SHK's operations are also to contribute to people having a sense of security and trust in societal institutions and confidence in transportation systems. SHK's assignment also includes assessing the contributions made by public rescue services in connection with an accident. However, the investigations are not to address issues of guilt, blame or liability for damages.

SHK accident investigations thus aim at answering three questions:

- What happened?
- Why did it happen?
- How can a similar event be avoided in the future?

The report is also available on SHK's website: www.shk.se

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Contents

Summary

The roller coaster Jetline has been at the Gröna Lund amusement park in Stockholm since 1988. The track was 800 metres long and a ride took approximately one minute, with a maximum speed of 90 km/h. The trains had a capacity of 14 passengers, distributed between seven cars.

On Sunday 25 June 2023 a train carrying eleven passengers crashed after having travelled roughly one third of the way round the track. At the time, there were three trains operating on the rollercoaster and the other two trains were located next to the place where passengers get on and off the ride. During the accident three people fell out of the train, which resulted in the death of one person and one person suffering serious injuries. Two of the passengers who remained seated in the train were seriously injured and the others escaped with minor injuries.

The fire and rescue service, ambulance service and police were called, and all passengers had been taken care of one hour after they arrived. The rescue operation was under the prevailing circumstances conducted in an efficient manner.

The accident occurred when the control arm (part of the wheel suspension) at the very front of the train broke. The parts of the control arm with wheels on either side of the train came completely loose and fell off. This led to sharp decelerations when the car's chassis sunk down towards the track and hit joints in the track structure.

The sharp decelerations resulted in the passengers being thrown forward against the lap bars. This resulted in three of the passengers falling out of the cars and some suffering serious internal injuries. The design and dimensioning of the lap bars contributed to the serious consequences for the passengers.

The break in the control arm occurred as a result of insufficient strength caused by defects in weld joints and because an essential part inside the tubular structure was missing. The control arm was one of five that was ordered and manufactured in 2019.

The investigation shows that when the control arms were ordered sufficient requirements were not set with respect to how they were to be manufactured and the manufacturing process itself. Nor were sufficient checks conducted of the workmanship during manufacturing and before the control arms started being used. The safety management system conducted at Gröna Lund did not result in adequate accident safety on the rollercoaster.

The investigation also shows there are deficiencies in the rules for amusement rides and insufficient public supervision.

The fact that the lap bars were not able to keep the passengers inside the cars during the accident and caused serious injuries means that there are reasons to consider whether the requirements with respect to the restraint of passengers on rollercoasters need to be changed.

Causes/Contributing factors

The accident was caused by failings in ordering, manufacturing and verification of new control arms on the trains operating on Jetline. This led to a control arm with insufficient strength being used on the train and breaking.

A contributing factor to the serious consequences of the accident was that the passenger restraint structure was not designed for the forces that arose.

Underlying factors for the accident at a systemic level were:

- The lack of a fixed and established method at the amusement park for identifying, assessing and managing risks associated with the attractions.
- Unclear rules concerning the operator's responsibility for safety.
- Insufficient public supervision.

Safety recommendations

Gröna Lund AB is recommended to:

- Improve its safety work relating to attractions so this, as a minimum, ensures that:
  - risks in the form of organisational and technical failings that may lead to accidents are continually identified, analysed and rectified,
  - procedures are drawn up which ensure that replacement parts comply with the requirements originally set for the attraction in question,
  - checks are tailored to the operating time of an attraction and identified risks,
  - the entirety of the safety work is frequently followed up, evaluated and, when necessary, revised (see section 2.3). *(SHK 2024:07 R1)*

The Swedish Police Authority is recommended to:

- Conduct a review of the regulations concerning amusement rides. The aim of this review should be to increase the level of safety, including by ensuring that:
  - amusement park and funfair companies' responsibility for safety is highlighted more clearly, including the fact that this responsibility encompasses all the measures required in order for the attraction to have satisfactory accident safety,
  - the need for systematic safety work is reflected,
  - specific requirements for checks and inspections are introduced in order to ensure that an amusement attraction has not been subject to alterations or interventions that may reduce the safety of the attraction,
  - the general advice concerning record-keeping is supplemented so that the record for each attraction also states what maintenance measures, alterations or interventions have been implemented on the attraction,
  - references to applicable standards are updated,
  - it is made clear that the requirements concerning operation and maintenance in applicable standards also encompass amusement attractions manufactured prior to 1 July 2006 (see section 2.4). *(SHK 2024:07 R2)*

- If the review leads to the Swedish Police Authority making the assessment that sufficient changes are not possible at the level of regulations, the Police Authority should hand over the matter of necessary legislative changes to the Swedish Government. *(SHK 2024:07 R3)*

The Swedish Government is recommended to:

- Take action to strengthen public supervision of amusement parks and funfairs. Stronger supervision should include the potential to implement continual supervisory measures and supervisory visits. These activities should also include advice and information for amusement park and funfair companies about the requirements placed on the safety of amusement attractions and how these can be complied with, for example through risk analyses and a systematic approach to safety work (see section 2.5). *(SHK 2024:07 R4)*

- When necessary, take action to ensure it is possible to bring about the changes to the regulations set out in the recommendation to the Swedish Police Authority *(SHK 2024:07 R3)*, or that equivalent changes are implemented through legislation. *(SHK 2024:07 R5)*

The International Association of Amusement Parks and Attractions (IAAPA) is recommended to:

- Disseminate SHK's final report to its members and in its safety forums in order to provide members with evidence upon which to assess whether there is a need to alter requirements for restraint devices in rollercoasters. When providing such information, the observations in the report about the need for a systematic approach to safety work and the use of replacement parts in rollercoasters should also be highlighted (see sections 2.3 and 2.6). *(SHK 2024:07 R6)*

The investigation

SHK was informed on 25 June 2023 that an accident had taken place on the Jetline rollercoaster at Gröna Lund in Stockholm just after 11:30 hrs that same day.

The accident has been investigated by SHK, represented by Director General John Ahlberk, chairperson, Tomas Ojala, investigator in charge, Daniel Söderman and Håkan Josefsson, operations and technical investigators.

SHK has been assisted by Element Materials Technology AB for materials technology investigations and by KTH Royal Institute of Technology when test running the rollercoaster.

Investigation material

- The accident site with track and trains has been examined.
- Interviews have been conducted with people who rode the train involved in the accident, witnesses to the occurrence, staff at Gröna Lund and the inspection company DEKRA, people who have had a connection to the manufacturing of control arms and operational personnel from the Greater Stockholm Fire Brigade.
- Orientation discussions have been conducted with representatives from Parks & Resorts Scandinavia AB, the Ministry of Justice, the Legal Department and National Operations Department of the Swedish Police Authority, the Swedish Consumer Agency and the Swedish Institute for Standards (SIS).
- Technical examinations have been conducted of the track and trains, including materials analyses.
- SHK has studied films from security cameras and drones. Photographs of the track and trains have been examined.
- Drawings and other technical and organisational documentation have been obtained and examined.
- SHK has studied email correspondence between Gröna Lund and subcontractors.

Information that has been obtained through the interviews and the orientation discussions has been incorporated into the report.

Factual meetings with the interested parties were held on 13 and 14 December 2023. At these meetings SHK presented the facts discovered during the investigation, available at those times.

1. Factual information

1.1 Circumstances

The accident occurred on 25 June 2023 on the Jetline rollercoaster at Gröna Lund. Jetline is an attraction that has been at the amusement park since 1988. On the day of the accident the temperature was c. 26 degrees, there was a light north-westerly wind and the sky was clear.

Figure 1. The Jetline rollercoaster is the light-blue track in the picture. Boarding and deboarding took place in the building that has a light arched roof at the bottom of the picture. Another attraction, Vilda musen, has its track integrated into the construction of Jetline and is visible here as a lighter stretch of track.

At the time, three trains were running simultaneously on the rollercoaster. Each train consisted of seven cars with space for two people in each car. In front of every seat there was a lap bar that was lowered down towards the person's stomach/thighs before departure. The trains ran on and were held onto the rails using a structure made up of wheels (bogies) on either side of the train. The bogies were mounted on a control arm under the train. There were two control arms on the front car and one control arm on the other cars. The forwardmost control arm was mounted with an axle in the middle so that the bogies were able to move vertically, and the other control arms were fixed in place (see Figure 2 and 3). The construction of the rollercoaster is described in more detail in section 1.5.

Figure 2. The front part of the train with the bogies with wheels above, under and on the sides of the rail. (The picture does not depict the train involved in the accident.)

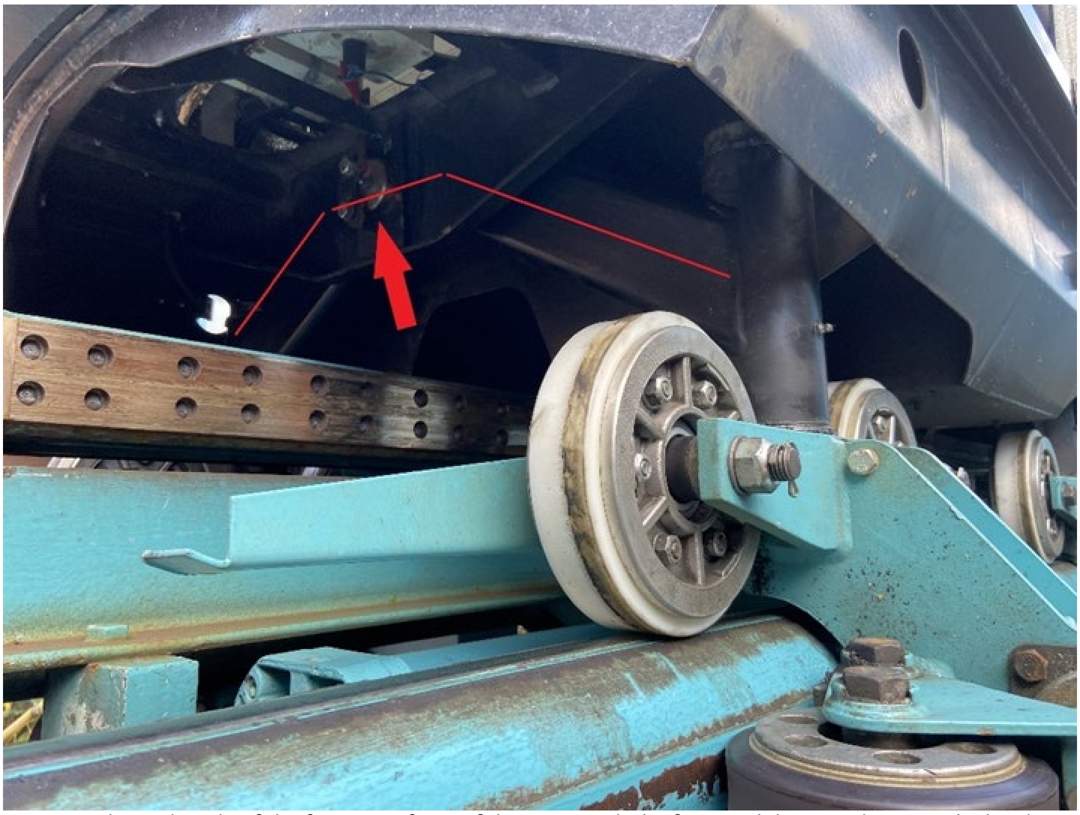


Figure 3. The underside of the front car of one of the trains with the front mobile control arm marked with a red line. The red arrow points to the end of the axle on which the control arm is mounted. (The picture does not depict the train involved in the accident.)

1.2 Sequence of events

1.2.1 The ride

The ride on the train involved in the accident started at 11:36 hrs. There were eleven passengers on the train, distributed across all the cars (see Figure 4). The staff did not notice anything abnormal with the train when it was stopped at the station and the passengers were boarding.

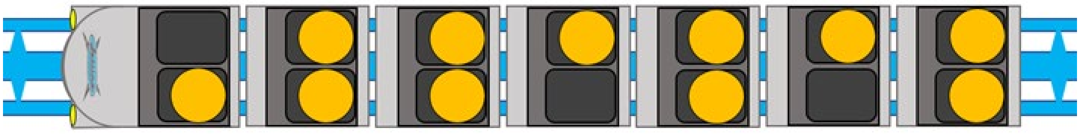


Figure 4. A yellow mark represents a passenger. The image shows how the passengers were seated in the train prior to the accident.

The train was pulled up to the highest point on the track, ran down towards the bend furthest away from the starting point, up to the second highest point and then down a steep right turn.

Some of the passengers interviewed, who had ridden the attraction previously, felt that the ride was different right from the start of the run. The ride was described by them as bumpier and there was more noise from the track than normal.

Down in the dip after the steep right turn, the train's chassis began scraping against the track. Just before the train reached the third rise, the right part of the front control arm came off completely, together with the right bogie. These parts fell down and first hit a part of the track underneath and then landed on a roof.

When the forwardmost bogie on the right side came off, the train fell down further towards the track and continued hitting the track. At the end of the third hill it hit the track hard and the entire track structure shook powerfully. In conjunction with the powerful impact, one person who was sitting on the left side of car five fell to the ground. The train then continued along the track in a descending right turn, at which point the left part of the control arm and associated bogie came off.

The chassis continued hitting the track and two people who were sitting in car seven fell out of the train. One of them fell to the ground and the other was able to get hold of one of the beams in the track structure, get up onto the beam and remain there.

The train continued at low speed and, a short distance up the next uphill section, rolled back a little and came to a stop. When the train stopped, it remained on the track with the front part of the first car twisted out towards the right.

1.2.2 Rescue operation

The rollercoaster's station staff saw that an accident had taken place and one of them called Gröna Lund's service technicians. Several technicians immediately headed to the rollercoaster because they understood that something serious had happened. At the same time, visitors to Gröna Lund had also heard and seen the accident. Several visitors began heading towards the fenced-off area of the rollercoaster in order to try and help.

The first call about the accident was received by SOS Alarm at 11:38 hrs. SOS Alarm called out the fire and rescue service and ambulance service and informed the police who called out their resources. The first resources from the fire and rescue service, Greater Stockholm Fire

Brigade, arrived at 11:45 hrs. After this, further resources from the fire and rescue service, the police, several ambulances and emergency doctors arrived. The rescue operation began with first aid for the people who had fallen down onto the ground and an order to rescue the people who remained on the train with a ladder truck. The incident commander also decided to evacuate Gröna Lund, which was implemented ten minutes later with the assistance of Gröna Lund's staff.

A ladder truck was driven forward in order to begin the work of taking down the person who was sitting on one of the rollercoaster's beams. However, it was not possible to reach the person with the ladder from the truck's initial location because of all the beams. But after a quick relocation it was possible to get the person down using the ladder. The ladder truck needed to be moved one more time in order to reach the passengers who were on the train. It was possible to reach all the people in the train from this location.

At the same time, a risk assessment was conducted for the work close to the train. Technicians from Gröna Lund contributed to this and the assessment was that the train was secure on the track after the front car had been secured. The technician followed the firefighters up in the basket of the ladder truck, secured the car and then helped to release the lap bars in the cars. This allowed the firefighters to lift the passengers into the basket. Because of the warm weather, water was given to the passengers who were not deemed to be seriously injured. Healthcare and fire and rescue service personnel received these people once the ladder was lowered to the ground.

Other means of getting the passengers down were also prepared. Specially trained fire and rescue service personnel and the police rapid response unit began setting up equipment in the structure of the rollercoaster that would allow the passengers to be lowered. However, bringing them down using the ladder truck proved to be sufficient.

The people who had fallen out of the train were taken care of by healthcare personnel. The first person was confirmed dead on site by an emergency doctor following resuscitation attempts. The second person was initially treated on site then moved with the help of the fire and rescue service to an ambulance in order to be taken to hospital.

One person in the train began intermittently losing consciousness. A paramedic was taken up to provide care while attempts were made to come up with a safe way to get this person down to the ground. However, this person's condition began to deteriorate and they needed to get to hospital quickly. Getting this person down using the basket on the ladder truck was the fastest option but moving the unconscious person from the train using the basket was deemed to be not entirely without risk. However, after one further firefighter had been brought up into the car it was possible to ensure this person would not fall and to lift them into the basket.

After just over an hour, all of the people in the train had been brought down using the ladder truck. Staff from Gröna Lund were themselves able to help the passengers who were on the other two trains on the track to get out.

The fire and rescue service operation was concluded at 14:52 hrs. The Swedish Police Authority cordoned off the area and decided on 30 June 2023 to prohibit the use[1] of the Jetline rollercoaster.

[1] File no. A380.167/2023.

1.3 Personal injuries

One person died and three people were seriously injured. Some of the people on the train suffered minor physical injuries.

The first person who fell out of the train suffered multiple fractures and serious internal injuries and died. The second person who fell out of the train suffered injuries including fractures in the face, arms and legs. The third person who fell out and ended up on a beam suffered minor injuries. The people who remained seated in car four and six sustained serious injuries, including injuries to the face, ribs and internal injuries. Some of the other people on the train suffered minor physical injuries.

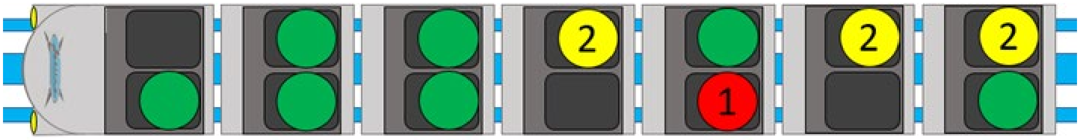


Figure 5. Positions on the train of the deceased (marked in red/1) and the people who were seriously injured (marked in yellow/2) at the time of the accident.

1.4 Material damage

The frontmost control arm broke into three parts. The middle part of the control arm remained in the car. Indentation damage was caused to part of the track and a sheet metal roof when the right part came off and fell down. When the left came off and fell, this caused the top edge of a fence next to the attraction to bend over and indentation damage to a pillar for the attraction's support structure. The train sustained extensive damage. The lap bars in the train's cars were bent when the people in the cars were pressed against them. The track was scratched and sustained damage to joints and nuts and bolts at the joints after having been hit by the train.

1.5 Construction of the rollercoaster

The Jetline rollercoaster was designed for Gröna Lund by the companies Schwarzkopf GmbH and Ingenieurbüro Stengel GmbH and began being used at the amusement park in 1988. The trains were manufactured by the company Zierer Karussell und Fahrzeugfabrik and the track by Bayrische Hütten Stahl. All these companies operated in what was then West Germany. None of these companies still exist in their original form, but the company name Zierer is still around and is being used by another German company that manufactures attractions ZIERER Karusell- und Spezialmaschinenbau GmbH & Co KG.

The rollercoaster had a track length of 800 m, with the highest point on the track being c. 30 metres. The maximum speed was c. 90 km/h and a maximum g-force of 4.5 could be achieved.

Various modifications were made to the attraction between 1999 and 2018. These included alteration of the track geometry, renovation of the chassis of the trains and installation of a new braking system.

1.5.1 Track structure

The rollercoaster had a station at ground level where passengers got on and off the trains. At the station there was a control room from where staff controlled and monitored the attraction. Directly after the station, the trains were pulled up to the highest point of the track by means of a chain-operated hitch. The train then rolled through the entire track from the highest point. The track was built in such a way that passengers were not lifted out of their seats due to negative g-forces and were not pressed against the sides to any major degree.

There were three places along the track with braking devices that were used when necessary to reduce the speed of or stop the trains. There was also a brake at the end of the track which reduced the speed at the end of the ride. The trains themselves were not equipped with brakes or other devices for adjusting the speed during the ride. Aside from brakes, there were also sensors along the track that detected where each train was. When a train passed one of these sensors, the track section up to the next sensor was reserved for that train alone. Each of these track sections needed to be passed within at preset time interval. If the train was going too fast, it was braked at the next brake and if it took too long, the train behind was stopped in order to prevent an impact from the rear.

There were two different types of brakes on the track. The original brakes were friction brakes, the pads of which were pushed outwards and gripped the chassis of the cars. Over the years, these brakes had started to cause wear to the cars and the track was supplemented with eddy current brakes that work by means of an electromagnetic field without any mechanical contact with the trains.

The track consisted of multiple segments that were bolted together. Each segment was between c. 4 and 6 metres long. The track segments were made up of two outer tubes that formed the rails on which the train ran and these were welded together with a wider tube in the middle. The segments were joined together at each end using bolted joints on a rectangular flange in the middle tube (see Figure 6).

Figure 6. Two track segments and the joint where they are bolted together.

There was a train workshop for maintaining and repairing the trains. It was possible to drive the trains into the workshop where they sat on rails that were specially designed for the need to allow the trains to be worked on.

1.5.2 Trains

There were five trains for the rollercoaster and three trains were used on the track at the same time. The trains were labelled A, B, C, D and E. It was train E that was involved in the accident and train A had been removed for inspection and maintenance at the time of the accident. Train C was parked outside the workshop and the intention was not to use it during the season.

In order for all the trains to have an equivalent speed and not be at risk of stopping, each train needed at least ten people aboard. Additional factors that affected the speed of the trains were temperature, precipitation and the friction of the wheels against the rails. The friction of the wheels could be adjusted by using harder or softer wheels. The softer wheels resulted in more friction and a lower speed.

Figure 7. One of the Jetline trains during one of the test runs conducted as part of SHK's investigation.

Cars

A train was made up of seven cars constructed from steel and external panels made of glass fibre-reinforced plastic. Each car had space for two people, a total of 14 people in one train. There was a side opening in front of each seat for getting in and out. The people were protected from falling out of the cars while the train moved around on the track by padded lateral supports, back supports and a lap bar that was lowered down manually against the person's stomach/thighs before departure. The lap bar held the person against the seat and the back support during braking but was also there to prevent a person from getting out of the seat themselves. There were no other passenger restraint functions.

The chassis of the cars was designed as an upside-down U where the steel plates for the brakes in the track were placed. There was a coupling between the cars that allowed vertical and lateral movements.

An empty train weighed c. 3,800 kg, with a maximum estimated weight of 4,900 kg when it was fully loaded (14x75 kg). Car 1 was the heaviest and weighed 786 kg, while the other cars weighed c. 500 kg. The estimated weight at the time of the accident was 4,600 kg.

Control arms and wheel structure

The control arms were originally manufactured from hollow square steel tubes with the dimensions 100x100 mm and a wall thickness of 5.6 mm. The square tubes consisted of three parts, two downward-angled parts and a middle part, which were welded at the joints. Welded to the end of the square tubes there were round tubes to which a structure with wheels (bogie) was attached. Each train had eight control arms. The first car had two control arms and the other six cars had one each. The control arm at the front of the train was attached to the car with a longitudinal axle in the middle that allowed the ends of the control arm to move up and down. The other control arms were fixed in place.

A bogie consisted of six wheels. Two wheels that rolled on the top of the rail, two horizontal wheels that rolled against the side of the rail and two wheels that rolled against the underside of the rail. There were a total of 96 wheels on the train.

Figure 8. A front control arm on a Jetline train with the hole in the middle for the axle attachment to the car.

Lap bars

The lap bar was a tubular steel structure that could be lowered from a hinge in front of the passengers' legs. The bar was padded closest to the stomach/thighs and on a transverse tube closer to the feet. There was a ratchet (tooth-rack) locking mechanism at the side of the car, which could be used to lock the bar in different positions. When the passengers were to get in and out, the bar was raised against the front wall of the car using a spring-loaded mechanism. The bar could then be pulled down into different positions but not lifted up by the person in the car.

Figure 9. The lap bars in the cars that were lowered against the stomach/thighs.

The staff in the rollercoaster's station building ensured that the bars were lowered and locked in place before departure. The locking mechanism had a spring-loaded button on the outside of the car for unlocking the bar. The button was depressed by a structure on the track close to the station building where the passengers were to get out, resulting in the spring-loaded bar lifting up. If a bar needed to be released separately this could be done using a special hand tool.

1.6 Technical examinations

1.6.1 Examination of the accident site

Examination of the rollercoaster with the train involved in the accident (train E) in the position at which it came to a stop following the accident was conducted on 26–29 June 2023. The entire track and train were photographed and filmed from a boom lift and using UAV (drone).

The accident occurred when the train was between the rises in the track where brakes 1 and 2 were located. This section of track began with a steep descent with a right turn towards a dip close to the ground. From the dip the track went up to a rise with a tens of meters long horizontal section. After the rise the track continued downwards in a right turn to a dip a few metres above the ground. It was there that the train involved in the accident finally came to a stop.

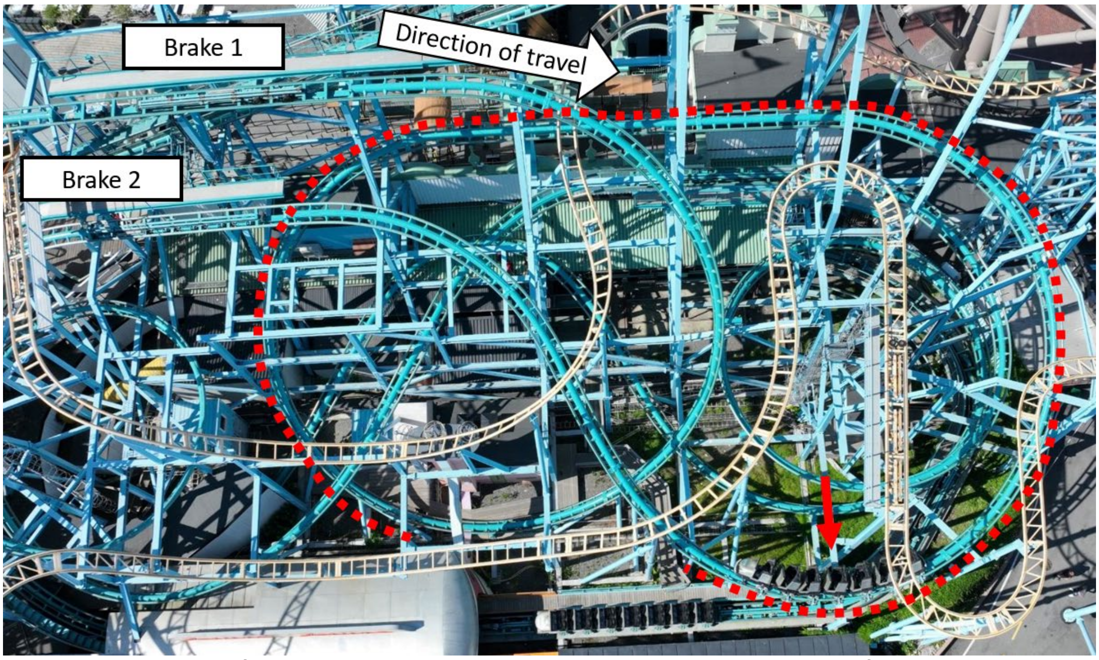


Figure 10. The section of track between brakes 1 and 2. The red dotted line is the part of the track where scratches and impact damage were found. The arrow points towards the train involved in the accident, which is in the bottom right of the picture on the dotted line. The station and the train that stopped there are visible at the bottom edge of the picture.

Scratches and impact damage were found during the examination. The first location where there was damage was a joint in the dip after the steep turn from the rise where brake 1 was located.

Figure 11. The first impact mark on the track. The red markings drawn in by SHK show were the impact occurred and the yellow arrow indicates the direction of travel. The black and white tape markings were added by the Swedish Police Authority.

After the first location where there was damage, sites of impact damage on the joints and scratches on the centre tube were found up to the location where the train came to a stop in conjunction with the accident. Sites where the impact damage was more severe that on the other sections of damaged track were noted up on the rise that came after the location in the dip where the first damage was found. Damage was found on one side of the nuts and bolts at two joints in a row. At this location the track leaned slightly to the right and the height of the track was measured at 13 metres.

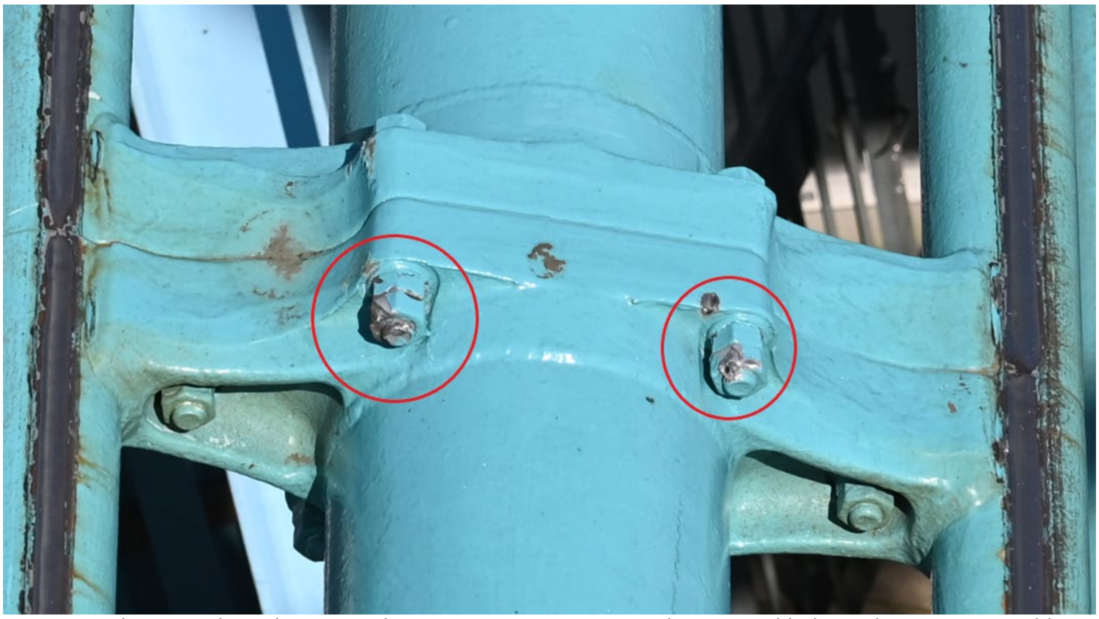


Figure 12. The sites where the impact damage was more severe on the nuts and bolts at the joints are visible within the red circles.

The damage was slightly less severe in the downward right turn after the rise where the most severe impact damage sites were located. The track here leaned to the right side and the cant was 50 degrees at the approximate position where the second person fell out of the train. The height of the track above the ground was eight metres at this point. The cant decreased from there up to the dip where the train came to a stop. The height of the beam where the person sat following the accident was six metres.

1.6.2 Examination of the train cars

The train cars were removed from the track and documented on site. The couplings between the cars were so badly damaged that some of the cars had to be cut loose in order to be removed. The cars and the wheels were transported to SHK's premises for further examinations. It was possible to establish that there was severe damage to the underside of the front car (see Figure 13). The other cars also had corresponding damage to their undersides but this was not as severe. The location of the damage was consistent with the scratches and impact damage on the track. The front of car three had been bent backwards in towards the seat (see Figure 14) and the lap bars had been bent to vary degrees in all of the places but one where people had been sitting (see section 1.6.4). Otherwise the cars were damaged in various ways.

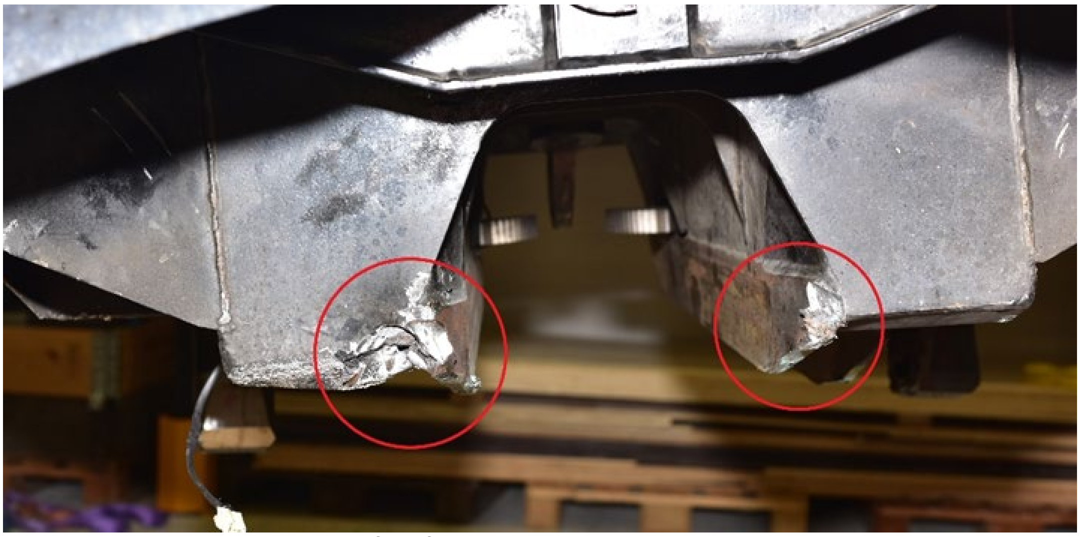


Figure 13. Damage to the underside of the front car. The red markings show were the impacts occurred.

Figure 14. Picture of the train following the accident. Note that the front of car three has bent backwards (marked with an arrow).

1.6.3 Examination of control arms

SHK commissioned Element Materials Technology AB to examine the front control arms. The aim of the examinations was to establish the mechanism of fracture and the reason why one of the control arms fell off.

Parts examined

Examinations have been conducted of five front control arms that were manufactured in 2019 and supplied to Gröna Lund in 2020 (see section 1.10.1). An original front control arm manufactured in 1986/1987 has also been examined.

The five front control arms manufactured in 2019 were:

- The control arm that broke on train E during the accident and which had gone c. 5,000 laps of the track.
- The control arm that was installed on train B in 2020 and which started being used in 2022. It had gone c. 29,000 laps of the track.
- Three control arms that had not been installed or used.

The control arms and parts from the control arm that was installed on train E were examined visually and with a low power microscope. The fracture surfaces from the broken control arm were examined fractographically[2] using a scanning electron microscope (SEM).

Some of the control arms that had not been installed on any train were x-rayed in order to check the workmanship on the welds that corresponded to those that broke during the accident. Two of the unused newly manufactured control arms, the used newly manufactured control arm from train B and the original control arm were x-rayed.

Metallographic cross-sections were prepared (cut-out pieces for examination in cross-section) through the weld on the original control arm, on one of the newly manufactured control arms and on the control arm from train B.

A crack in the weld on the control arm from train B was broken up and examined fractographically using a scanning electron microscope.

Examination of fracture surfaces

The starting point for the examination was the remaining middle part of the control arm that broke. The fracture surfaces were examined on both the right and the left sides. The examination showed that the weld encompassed only around half of the wall thickness. The welds also had continual and extensive adhesive defects[3] along the entire root (inside of the weld). This was deemed to be a serious welding defect that, at this extent, has a major impact on both static strength and on resistance to fatigue. In some places, grooves from the processing prior to welding were still present (see Figures 15 and 16).

[2] Fractography – description of the appearance of fracture surfaces.

[3] Insufficient fusion of the material during welding.

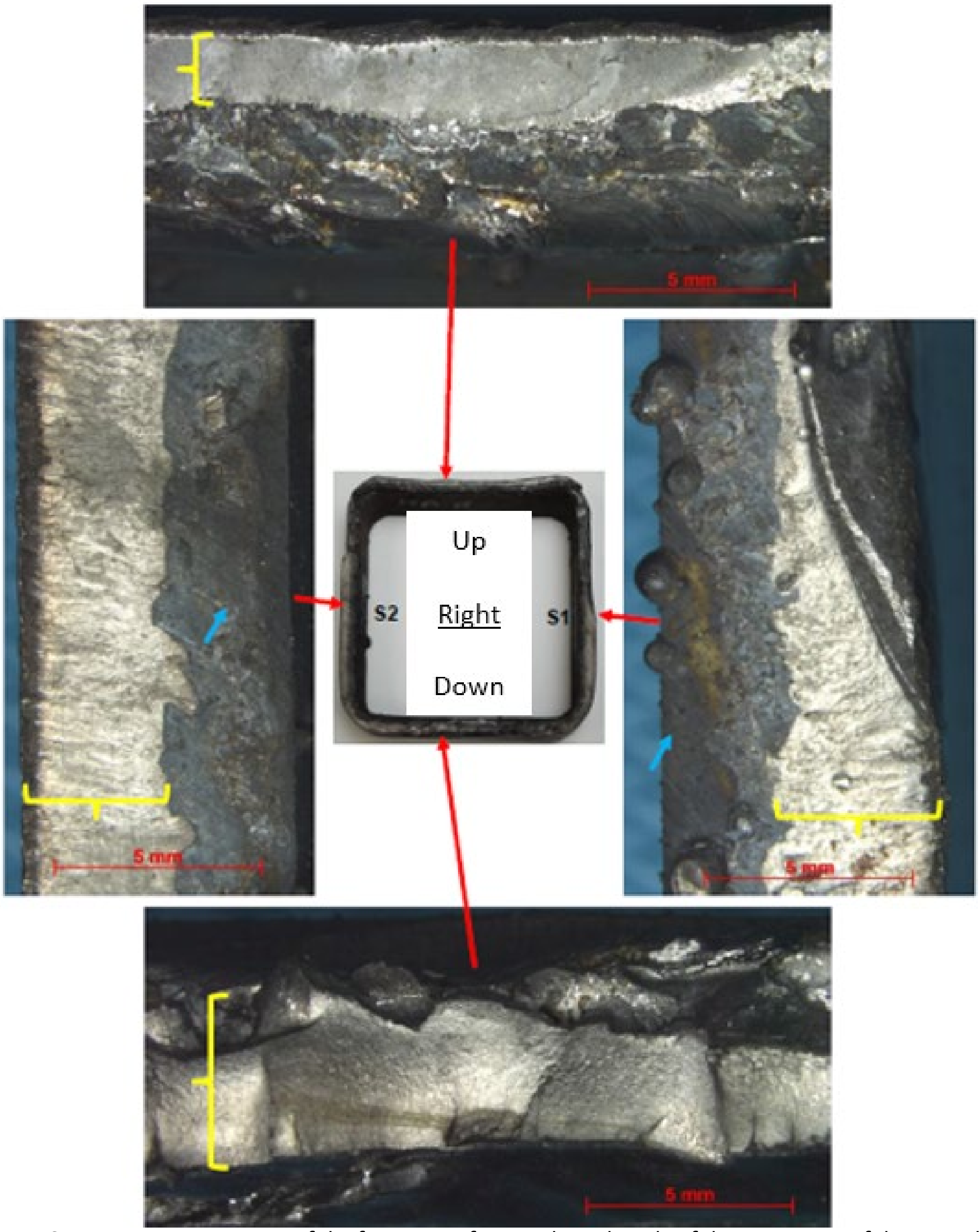


Figure 15. Stereomicroscopic image of the fracture surface on the right side of the centre part of the control arm. The thickness of the weld is indicated with yellow brackets in the images. Blue arrows in the figures show processing streaks that are still present from before the welding. Image: Element Materials Technology AB.

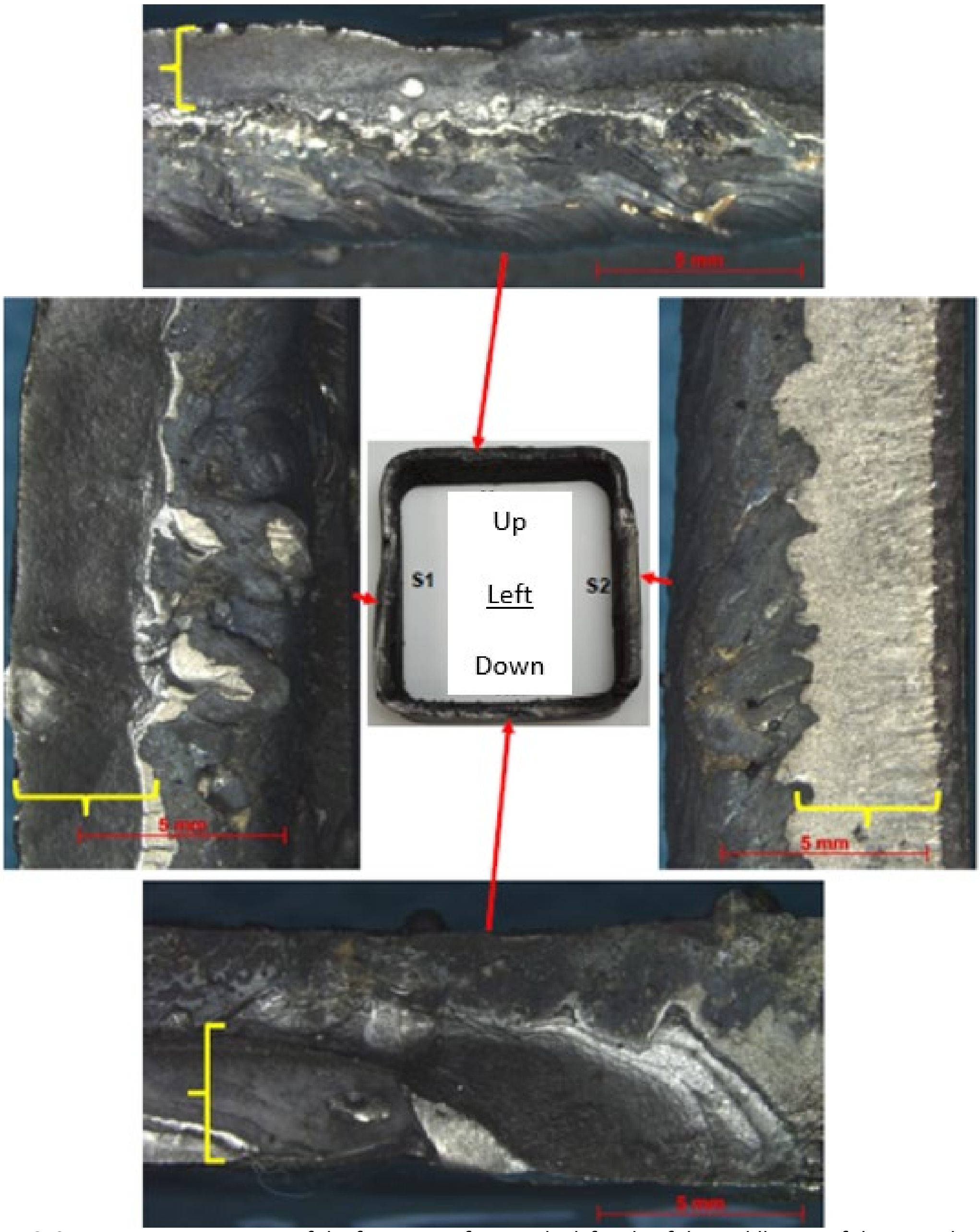


Figure 16. Stereomicroscopic image of the fracture surface on the left side of the middle part of the control arm. The thickness of the weld is indicated with yellow brackets in the images. Image: Element Materials Technology AB.

The fracture surfaces were also examined using a scanning electron microscope. During this examination it was possible to establish striations[4] on both the right and left fracture surfaces. This showed that a fatigue fracture had started from the root side/inside of the control arm (see Figure 17).

[4] Striations are the wave pattern that forms in the material when it is subjected to fatigue.

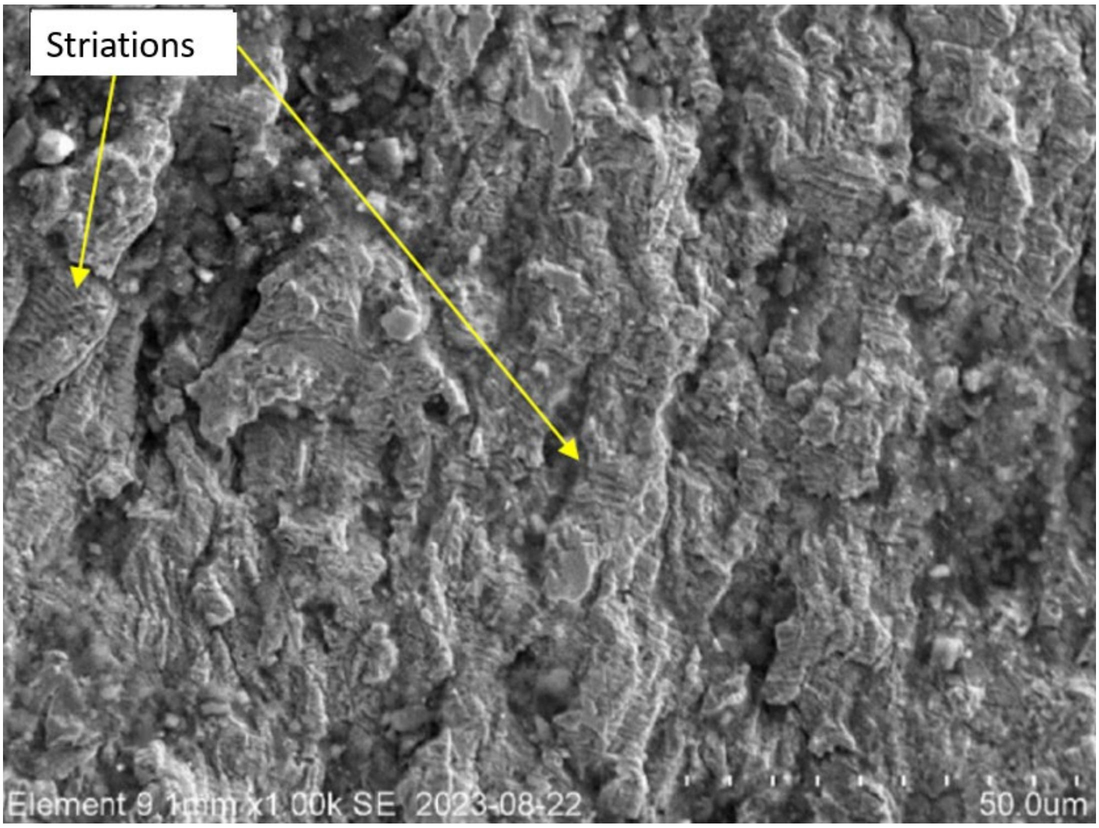


Figure 17. SEM image of one of the fracture surfaces on the right side of the control arm. Image: Element Materials Technology AB.

Examination of original control arm and newly manufactured control arms

A control arm manufactured in 2019 that had not been installed and an original control arm were cut up in order to facilitate a visual inspection of the inside of the part that corresponded to the place where the welds failed. The newly manufactured control arm did not have the transverse metal plate that was present in the original on the inside of the tube at the welded joint. X-ray examinations showed that the metal plate was also absent on the other newly manufactured control arms.

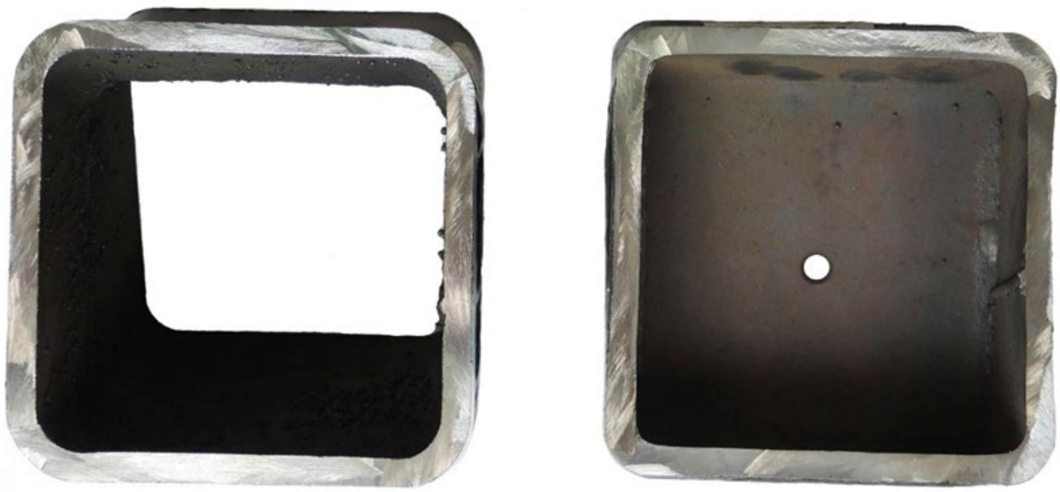


Figure 18. Cross-sections of two cut-up control arms. Original control arm manufactured in 1986/87 on the right and control arm manufactured in 2019 on the left. Image: Element Materials Technology AB.

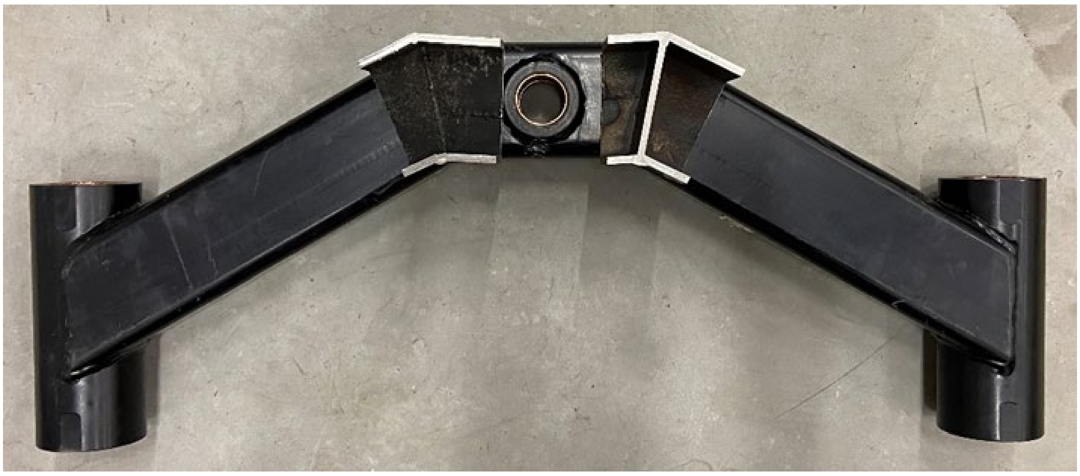


Figure 19. The picture shows a control arm with cut-out samples laid on top. The sample on the left is from a control arm manufactured in 2019 and the one on the right is from an original control arm. The transverse metal plate that is absent on the left is visible in the section on the right.

Two cross-sections were cut out of the weld on the original control arm and two from one of the newly manufactured control arms, one sample from a corner and one from a side. There was nothing remarkable about the weld on the side of the original, but the weld on the newly manufactured control arm had improper welding fusion. The weld in the corner showed adhesive defects in both of the samples.

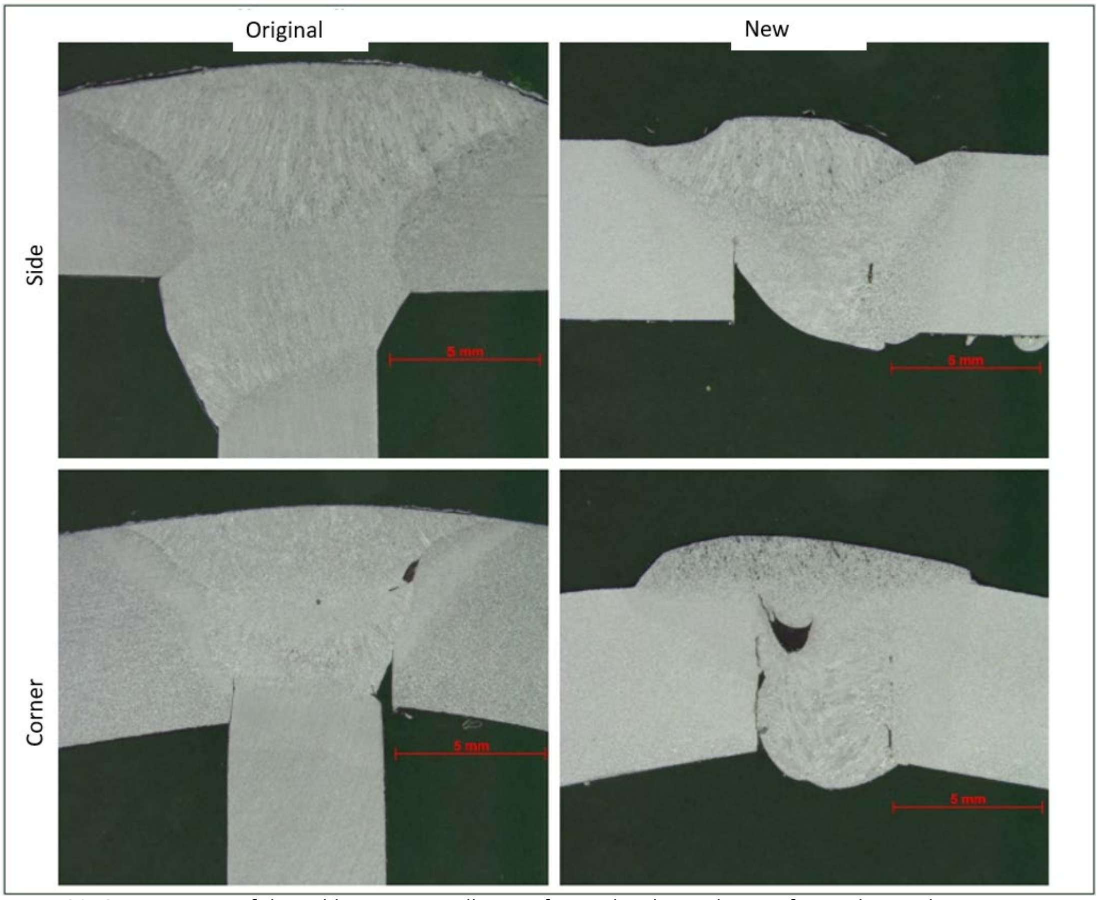


Figure 20. Cross-sections of the weld on an originally manufactured and a newly manufactured control arm. Image: Element Materials Technology AB.

The weld joints on the newly manufactured control arms had extensive adhesive defects in the roots and were so uneven that they could cause cracks. A crack that had begun in the adhesive defect in one of the corners of the weld was found on the inside of the control arm that had been in use on train B since 2022. The crack had a length of approximately 40 μm.

The crack was broken up and an image from the scanning electron microscope examination showed that the crack has occurred due to fatigue.

The examination of the control arms also showed other anomalies on the control arms from 2019. In Figure 20, which shows the cross-section of the weld joints, it is possible to see that the root gap, the distance between the tube sections, is smaller than on the original control arm and the material on the tube sections is right-angled instead of bevelled. There were also anomalies in the form of uneven and sharp edges on the outside of the weld joints; on the original control arm there was an even and smooth transition from the weld joint to the rest of the material. The weld joints were also thinner than the material in the steel tubes, which meant that the weld was not able to cope with as large forces as the steel tube.

Element Materials Technology AB concluded that the reason why the break occurred was faulty execution of the welding and deviation from the original design. The transverse metal plate inside the control arm where the weld is, which was to function as a stiffener and also as a backing bar (material instead of empty space at the base of a joint that is to be welded) when welding, was absent. The absence of this transverse metal plate meant that the forces were not distributed away from the joint, which resulted in it having a lower strength. The absence of a backing bar also made the welding more difficult and reduced the chances of executing a good weld.

Scrutiny of the drawing

During the investigation, SHK and Gröna Lund have each engaged an expert in order to scrutinise the drawing that was appended to the order for the front control arms. The aim of this scrutiny has been to assess whether the drawing was adequate supporting documentation for manufacturing.

The opinion from Gröna Lund states that the drawing '*works well as supporting documentation for manufacture*' and that '*the drawing is clear with regard to the shape of the butt welds with bevel angles, including the reinforcement plates that were used as backing bars for welding*'.

The expert that SHK engaged states that the drawing did not specify that the component is to have reinforcement plates. Furthermore, they state that the drawing, among other things, should contain separate drawings for the constituent components.

1.6.4 Examination of the lap bars

The train and the lap bars were examined with the aim of establishing how passengers in the train involved in the accident were able to fall out of the cars. The bars were examined both in the cars and after they had been removed. Load tests were also performed.

Position and function of the bars in the cars

During the rescue operation, the bars were raised in those places where passengers were evacuated. The bars in the empty spaces on the train and in those places from where the three people who fell out had been sitting were not touched during the rescue operation. The bars were then left untouched until the examination of the train once it had been lifted down from the track.

All but one of the bars from where people had been siting showed deformations; they had been bent forward to varying degrees. The largest bend was found in the lower part where the tubing of the bar transitions to an angled sheet metal. The bars in cars 5 and 7 had the largest deformations. The bars where the three people who fell out were sitting were in an almost entirely raised position.

The locking mechanism, which kept the bars lowered in different positions ahead of a ride, were inspected and were intact in all of the cars. The position in which the bars were locked by the locking mechanism showed that all of the bars had been lowered against the passengers before the accident.

Figure 21. The lap bar from car 5, left, has been placed behind an un-damaged bar. The bar from car 5 was bent forward c. 30 degrees to an almost open position during the accident.

Tensile test of the lap bars

Two tensile tests were performed in order to gain an understanding of approximately which forces the bars were able to withstand with before deforming. A car with the front removed was secured so that it was not able to move. The bars were then pulled by means of a chain hoist and a dynamometer (device for measuring force) until they deformed. The direction of pull had an angle of between 70 and 90 degrees to the bar (see Figure 22).

The tests were performed with the bars in two different positions. One bar was pulled down nine notches on the locking mechanism, the distance to the seat was approximately equivalent to the distance that a child would have. The second bar was only pulled down three notches, the distance from the bar to the seat would then correspond to that for a large adult.

Both tests had similar results; at approximately 1,400 newtons (just over 140 kg) the bars deformed in the same place as the bars had deformed in the train that was involved in the accident. Before the bars deformed they bent elastically, i.e. in such a way that they returned to their original shape when unloaded. During the test running of Jetline (see section 1.6.6), the force from a dummy against the bar was measured at 31.3 kg during sharp braking equivalent to an emergency stop.


Figure 22. Rigging used during load tests on a lap bar.

1.6.5 Examination of surveillance camera footage

SHK has examined security camera footage that showed parts of the area of the attraction. The footage did not record the entire sequence of events. It was possible to establish that the entire structure shook powerfully on two occasions. Just after the first powerful shake, it was also possible to establish that one person fell out of the car and the second person fell out of the train after the second shake.

One of the cameras was filming towards the dip where the first scratches and impact damage were found. A comparison was conducted of the position of the train on the track prior to the accident and at the time of the accident during the run up after the dip. When the train involved in the accident passed the dip and was on its way up, the front part of the first car was farther out to the left compared with the other trains, which suggests that the right bogie was no longer holding the train on the track.

1.6.6 Test runs

Test runs of Jetline with measurement equipment were conducted on 25 and 26 September 2023. The aim of these tests was to measure the g-forces and speeds that a train achieves on the track. The aim was also to measure the forces against the lap bar during sharp deceleration of the train. Train D was used for the test and was run without passengers but was loaded with two different loads that were controlled using weights on the floor of the cars. The train was both loaded with a maximum load and with a load that was equivalent to the weight at the time of the accident. Sensors were installed on the train in order to measure accelerations in three different directions and the speed was measured via the wheels on the train. Several cameras were installed in order to document the test runs. A test dummy that weighed 84 kg was placed in the rear car and was equipped with a sensor in order to measure the load against the lap bar during braking.

The results of the test run showed that the maximum load downwards in the car during a ride was 4.7 g and this was measured in the front car on the train. This force was measured at the position on the track where the impact damage was noted. At this point, the train had a speed of 88.0 km/h. The maximum speed recorded was 93.2 km/h, just before the location of the first impact damage to the track. A speed of 54.7 km/h was measured at the point where there were most powerful impacts on the nuts and bolts had been noted.

A force from the test dummy against the lap bar of 31.3 kg was measured during maximum braking at the last brake on the track.

Figure 23. Picture from the test run that shows the train in the position of the first impact on the track. At this time, the speed was 88 km/h and the load was 4.7 g in the front car.

1.7 Regulations and standards

The requirements for amusement rides are governed legally through:

- The Public Order Act (1993:1617).
- The Ordinance (1993:1634) on Inspection of Amusement Rides.
- The National Police Board's regulations and general advice on inspection of amusement rides (RPSFS 212:15 FAP 513–1).

More detailed requirements are set out in standards to which FAP 513–1 refers.

1.7.1 Public Order Act

By virtue of Chapter 2, Section 13 of the Public Order Act, amusement rides, including rollercoasters, may be used at public gatherings, public events and be provided to the general public in other cases only if they provide satisfactory accident safety and if they are inspected. It is the person or company who arranges the gathering or event that is responsible for ensuring the amusement rides are approved. This provision encompasses both travelling funfairs and permanent amusement parks such as Gröna Lund.[5]

The Government or the authority determined by the Government is able to issue regulations concerning testing, inspection and prohibitions against use of an amusement ride (Ch. 2, Section 13, second paragraph of the Public Order Act). Such regulations are set out in the Ordinance (1993:1634) on Inspection of Amusement Rides.

1.7.2 Ordinance on Inspection of Amusement Rides

The ordinance contains provisions concerning inspection, approval and prohibition of the use of an amusement ride. Furthermore, it contains provisions concerning the requirement for accreditation for inspection bodies that conduct inspections pursuant to the ordinance.

An amusement ride shall be inspected before it is first brought into use and then on regularly recurring occasions thereafter. If the ride has been altered in any respect that is of significance to safety, it must be inspected again (Section 3).

During the inspection, the inspection body shall verify that the amusement ride has been implemented in a manner that is consistent with applicable regulations and which is otherwise satisfactory from the perspective of safety (Section 4). If an inspection shows that these requirements are met, the inspection body shall issue a certificate of approval that is valid for one year.

If an amusement ride, due to damage or for some other reason, does not offer satisfactory accident safety, the Swedish Police Authority shall prohibit the use of the ride for as long as the fault remains (Section 9).

The Swedish Police Authority is able to issue more detailed regulations concerning testing, inspection and prohibition.

1.7.3 The National Police Board's regulations and general advice on inspection of amusement rides

By virtue of the powers granted through the Ordinance on Inspection of Amusement Rides, the then National Police Board has issued regulations and general advice on inspection of amusement rides (RPSFS 2012:15 FAP 513–1).

The regulations include provisions concerning the inspections that have to take place pursuant to the Public Order Act in order for an amusement ride to be permitted to be provided to the general public. Among other things, an initial inspection is required before the amusement ride is brought into use in Sweden (Section 8). Furthermore, there are provisions concerning annual recurring inspections (Section 9) and a detailed recurring inspection every five years (Section 10). The annual inspection shall include checks of all parts of the ride that are of significance to safety with respect to wear and tear, cracks,

[5] Berg, Ordningslag (1993:1517) 2 kap. 13 § [The Public Order Act (1993:1517), Ch. 2, Section 13], Karnov 21/02/2024 (JUNO).

damage, corrosion etc. And the detailed inspection shall include checks of all loadbearing parts with a focus on crack formation and damage caused by fatigue.

If necessary in order to enable the inspection body to assess whether the ride meets the requirements at the time of the detailed inspection, parts or components shall be disassembled. If this is necessary in order to assess the condition of loadbearing parts of the ride, essential non-destructive testing shall be conducted by an accredited testing laboratory.

Inspection may only be done by an inspection body that is accredited by the Swedish Board for Technical Accreditation (Swedac).

During an inspection, the inspection body shall ensure that the amusement ride has the safety level that applies by virtue of certain more specific standards, including SS-EN 13814:2005 – *Fairground and amusement park machinery and structures – Safety*, or lives up to at least the same safety level. Only those amusement rides that meet with these requirements are deemed to provide satisfactory accident safety. However, for amusement rides manufactured prior to 1 September 2006, the safety level set out in the older standard SS 767 70 01 from 1996 applies instead of SS-EN 13814:2005 (more information in section 1.7.4).

The general advice to the regulations concerning amusement rides states that the staff shall have suitable training and experience, that continual in-house checks of the ride shall be conducted in the form of, among other things, continuous supervision and that records are kept for each amusement ride that can be presented during an inspection.

If a ride has been altered in any respect that is of significance to safety, it must be inspected again (revision inspection, Section 11). According to the general advice to this provision, such alterations include, for example, the renovation, extension or repair of an amusement ride. A revision inspection includes checks to ensure that the ride is consistent with the scrutinised documentation, including drawings.

After passing an inspection a certificate of approval and an inspection sign shall be provided to the operator or owner of the amusement ride (Section 12). If the inspection body finds that, due to damage or for some other reason, an amusement ride does not offer satisfactory accident safety, the inspection body shall submit written notification to the Swedish Police Authority in the place in question (Section 16).

The general advice also states that, in conjunction with a decision to authorise a public gathering or public event, the Swedish Police Authority can inspect an amusement ride and issue those additional conditions that are required. An inspection of this type is normally restricted to verifying that the ride is consistent with the drawings, assembly instructions and similar, and that the stipulated safety devices are present. In larger permanent amusement parks such as Gröna Lund, the Swedish Police Authority essentially conducts no inspections before authorisation is granted to the public event. To the extent that the potential to conduct an inspection is applied, this is done primarily to smaller travelling funfairs. It is the Swedish Police Authority in the place where the public event is to take place that conducts the examination.

1.7.4 Standards

Standards referred to in FAP 513-1

FAP 513–1 states that amusement rides shall, as a minimum, have the safety level that applies by virtue of the standard SS-EN 13814:2005. This standard was replaced by SS-EN 13814:2019 in 2019. During the investigation, the Swedish Police Authority has stated that the standard from 2019 replaces SS-EN 13814:2005, which has been revoked, when applying FAP 513–1.

The standards from both 2005 and 2019 are extensive and set minimum requirements for safe design, manufacture, operation and maintenance. The basic safety levels are the same in the two standards. Among other things, it is specified that replacement parts must be consistent with the original part and that the person responsible for the ride attraction shall ensure that parts which are replaced have the correct specifications. However, the standard from 2019 has more detailed requirements in certain respects and refers to other, more recent standards.

With regard to welding procedures, reference is made in the standard for 2019 to the standard EN ISO 3834 (replaced EN 729 from 2006), which sets requirements on management control and descriptions for checks before, during and after welding. These include that a *Welding Procedure Specification (WPS)* and a *Welding Procedure Qualification Record (WPQR)* have to be drawn up before each welding procedure. The procedures shall describe how the weld is to be executed, using which welding materials and by whom. Furthermore, reference is made to the standard EN ISO 9696-1, which sets requirements that the welder have a valid welder qualification certificate for the relevant type of weld, known as a weld licence. This means that, before manufacturing takes place, the welder has to have welded test specimens in a way that is equivalent to that which is to be manufactured. The results then have to be checked and approved by a person from an accredited body.

FAP 513–1 contains a transitional provision which states that for an amusement ride manufactured prior to 1 July 2006 the safety level in accordance with the older standard SS 767 70 01 shall apply instead of SS-EN 13814:2005. During the investigation, the Swedish Police Authority has stated that the purpose of the transitional provision was to give amusement park and funfair companies the opportunity to adapt older amusement rides to the new standard over time.

Up until 2005, SS 767 70 01 served as a guide for the manufacture, design and execution of amusement rides. Unlike the standards SS-EN 13814 from 2005 and 2019, SS 767 70 01 specified no requirements or specifications for operation, maintenance and repairs.

Requirement for restraint devices for passengers

The standard, DIN 4112, that was applicable when Jetline was built contained only general requirements on the design of passenger restraints. It was required that passenger compartments should be designed so that passengers could travel safely in the vehicle. The vehicle was to have permanent seats and devices to hold on to. There was also to be retention devices if it was possible for the passenger to lift out of or slide off the seat.

The standard SS-EN 13814-1:2019 has more detailed requirements for the design of retention devices. The design requirements are based on calculations of dynamic forces that passengers might be subjected to in normal operation. Depending on the forces, there are various classes and subcategories for how retention devices are to be designed.

None of the standards from the period in which Jetline was built, up until the most recent applicable standard from 2019, specify requirements for the design of retention devices for scenarios in which the passengers are subjected to forces other than those calculated for normal operation.

1.7.5 Regulations and supervision for some related areas

Product Safety Act

The Product Safety Act (2004:451) implements Directive 2001/95/EC of the European Parliament and of the Council of 3 December 2001 on general product safety and contains provisions whose aim is to ensure that goods and services supplied to consumers do not cause injuries to people. As a general safety requirement, it specifies that goods and services supplied by a trader shall be safe (Section 8). Goods or services are safe if, in normal or reasonably predictable use and lifespan, they are associated with no or a low risk to human health and safety. However, this risk must be acceptable taking into account how the goods or services are used and shall be consistent with a high level of protection when it comes to human health and safety. Goods or services are dangerous if they do not live up to the requirements for safe goods or services (Section 9). The act contains provisions concerning, among other things, disclosure requirements, recall, harm prevention measures and supervision (market surveillance).

The Product Safety Act is only applicable if the goods or services are intended for consumers or may end up being used by consumers (Section 2). This is deemed to entail a requirement that there be some form of active use of the goods or services on the part of the consumer. For example, soft play centres are deemed to be subject to the act together with organised activities within climbing, highwire courses, bungy jumps and ziplines. However, services like public transport or rollercoasters, where the consumer only passively uses the service, are deemed to fall outside the scope of the act. For bungy jump equipment and ziplines, the provisions concerning amusement rides in the Public Order Act (1993:1617), with requirements for inspection and approval pursuant to the Ordinance (1993:1634) on Inspection of Amusement Rides, also apply.

The Swedish Consumer Agency has overall supervisory responsibility under the Product Safety Act and conducts market surveillance. The supervision shall be effective and ensure compliance with the act and the regulations issued by virtue of it (Section 25). The supervisory authority has extensive powers in conjunction with supervision, encompassing areas including injunctions, prohibitions and fines. Traders who intentionally or negligently violate the provisions of the act can be ordered to pay an administrative fine.

Within the scope if its supervision, the Swedish Consumer Agency runs advisory activities for traders on how to comply with the requirements in the Product Safety Act, through means including guides on how to offer safe services to consumers and information about preventative safety work. Within the scope of preventative efforts there is an emphasis on, among other things, the need for risk analyses, documentation of safety work and a coherent system for reporting incidents and accidents. [6]

Lifts and certain other motorised devices

The planning and building legislation contains technical requirements for motorised devices in constructions. There are also requirements concerning inspection of such devices and requirements concerning where and when they may be used. These include provisions

[6] Vägledning för att erbjuda säkra tjänster till konsument [Guide to offering safe services to the consumer], Swedish Consumer Agency, 2017.

concerning inspections of the device the first time it is brought into use or after it has been altered (revision inspection, Ch. 5, Section 8, para. 1, point 3 of the Planning and Building Ordinance (2011:338). The requirements are specified further in regulations from the Swedish National Board of Housing, Building and Planning.[7] In addition to lifts, the regulations encompass motorised devices that are intended for transporting people or goods, for example escalators, travelators and cableway installations. Amusement rides are explicitly exempted from these regulations.

The implications of these regulations include the following.

The owner or the person who is otherwise responsible for the motorised device shall ensure that it is inspected, that in-house supervision is conducted and that an accredited inspection body conducts inspections at the stipulated intervals. The device shall continually be supervised, taken care of and maintained so that it provides satisfactory protection of safety and health. When altering a device or replacing a certain part of the device, the altered or replaced part shall comply with the requirements in the regulations. A record shall be kept with notes about all inspections, maintenance measures and alterations.

Inspections shall be conducted before a device is brought into use, recurrently and when the device is altered. At the time of recurring inspection parts of the device that are of significance to safety shall be checked, as shall whether the device complies with new requirements that have been set after it has been installed. The device shall also be checked to ensure it has not undergone any alterations or interventions that may affect its safety, BFS 2018:2 H18.

The municipality's building committee is the supervisory authority and conducts supervision to ensure compliance with the requirements. The supervision is directed at the person who owns or is in some other way responsible for the device.

1.8 Gröna Lund AB

The amusement park Gröna Lund on the island Djurgården in Stockholm, which has, among other things, a large number of rides and concert events, began operating in 1883. Gröna Lund became part of the group Parks & Resorts Scandinavia AB in 2001. In 2023 the group consisted of the amusement parks Gröna Lund, Kolmården, Furuvik and Skara Sommarland. All of the amusement parks in the group are run as separate limited companies. The year before the accident, 2022, Gröna Lund had almost 1.3 million visitors.

1.9 Gröna Lund's safety work

The safety work conducted by Gröna Lund has been described verbally to SHK partly with the help of an organisational outline drawn up during the investigation. Aside from the organisational outline, SHK has been able to study documentation for checks and inspections and documentation for long-term assessment of the lifespan of attractions. No documentation has been presented that provides an overall description of the work involving safety and which was applied at the amusement park.

Overall, Gröna Lund's safety work has been described as being split up into a part for attractions and a part for guest safety in general. Guest safety encompassed, among other

[7] Swedish National Board of Housing, Building and Planning's regulations amending the board's regulations and general advice (2011:12) on lifts and certain other motorised devices, BFS 2018:2 H 18.

things, issues relating to safety at concerts and generally when guests were in the amusement park. There was a specific function for work environment-related safety issues.

The investigation has been restricted to the safety work relating to operation of the attractions.

1.9.1 Safety work relating to operation of the attractions

Safety work relating to operation of the attractions was conducted within various departments and forums under the leadership of a head of attraction safety. The head of attraction safety also had an advisory function at the group level within Parks & Resorts. Gröna Lund was the largest amusement park in the group and the safety work there was deemed to set the standards for the other parks.

The safety work relating to the attractions was split up organisationally into a part for technique and safety (the technical department) and a part for operations (the operations department). The technical department was responsible for ensuring the attraction functioned, and those who operated the attraction were in the operations department. There was continual dialogue between the departments, with the engineering department, for example, handling fault reports from the operations department. The engineering department dealt with maintenance, inspection and other technical measures. Among other things, it also handled contact with inspection bodies and manufacturing companies, as well as the training of mechanics for the attractions.

Technical safety measures for attractions were largely based on checks and maintenance being conducted in accordance with the stipulated intervals. The checks were conducted by staff with various qualifications and competencies. Full-time and seasonally employed mechanics performed more extensive inspections and maintenance and rectified faults that arose. Seasonal staff who worked with operating the attractions for guests submitted fault reports when anomalies were detected.

Otherwise, servicing, maintenance and development of and investments in the attractions took place in accordance with the manufacturer’s instructions and, if possible, in dialogue with the manufacturer.

Safety forum for the attractions

Safety issues relating to the attractions were dealt with in forums in various sub departments of the technical department. Issues concerning the safety of guests and members of staff, incident reporting, coordination within the engineering department and ongoing projects were highlighted at weekly meetings. Various heads of department and various experts participated in these meetings.

At the end of the operating season there was a forum for evaluating maintenance requirements and once or twice per year there was a forum for establishing a long-term plan for attractions. The head of attraction safety and other managers higher up in the organisation were involved in these forums. The forums addressed, among other things, issues including operational safety and development and safety of guests and employees.

The long-term plan was produced taking into account factors including operational safety and lifespan. These occasions were also used to decide on priorities for investments in safety and development of attractions. The long-term plan for Jetline was to replace the control system that controlled the rides. Otherwise no other planned measures for Jetline were described, aside from the checks and inspections that were performed regularly.

There were a large number of registration and evaluation systems where, for example, fault reports, incidents and planned measures were entered. For a long-term project involving all the attractions, year of construction, age of control systems and maintenance costs, for example, were registered. This was to give an indication of the lifespan of the attraction and its future maintenance and investment requirements.

1.9.2 Checks and inspections conducted on Jetline

In-house checks

There was a structure for the checks that Gröna Lund conducted using its own staff (in-house checks). In-house checks of the rollercoaster Jetline were governed by checklists and the actions were recorded in logbooks. In-house checks also encompassed various types of maintenance measures.

The checklists specified the checks that were to be performed daily, weekly, every two weeks and monthly. These checks were based on visually assessing the state of the structures and performing functional tests.

Daily in-house checks were performed by attraction mechanics in the workshop before the trains was put into service. The underside of the trains, their wheels and top side were visually inspected and certain functions were checked, including the function of the lap bars. Checks on the underside of the trains included verifying that the bolts and screws were tight and whether there was any wear on the hooks for pulling the train up the track. Each bogie was lifted a little bit off the rail so that it was possible to spin the wheel to check whether the wheel and the bearing were free of defects. In addition, the control arms were visually inspected for any visible defects. On the track, the brakes and installations in the station building were checked by test running a train.

An emergency stop when a train was running on the track was performed once a week. Every other week a visual inspection was conducted of the steel structure of the track and the couplings between the cars. A winch for recovery of trains was checked every month.

The logbooks for in-house checks that were scrutinised by SHK did not show any discrepancies in terms of intervals or execution. Nor were there any discrepancies registered from the daily checks on the train involved in the accident on the day of the accident.

Inspections

According to logbooks from Gröna Lund, the inspections of Jetline have been conducted at the stipulated interval. The inspections were conducted in such a way that the annual inspection involved checking the entire ride and a detailed inspection was conducted on one of the five trains. This meant that all five trains were subjected to detailed inspections within the stipulated five-year interval. The inspections were ordered by Gröna Lund and were conducted in collaboration the accredited inspection company DEKRA Industrial AB (DEKRA). At the time of the accident there was a valid certificate of approval issued by DEKRA.

During the annual inspection, the track itself was checked more thoroughly and various types of maintenance measures were implemented. The trains were disassembled for checks and non-destructive testing. Faults that emerged during the inspections were rectified and new checks were performed.

Non-destructive testing

Non-destructive testing involves methods for testing materials without the material or a structure being damaged. The testing methods require training and certification. There is a brief description below of the three methods used to detect superficial defects in the material during the inspections of Jetline. A record of the method and results of the test was issued after each test.

- Visual testing – Is performed using the tester's own visual impression.
- Magnetic particle inspection – Is used to find defects on and just under the surface of ferromagnetic materials such as steel. The method involves the material being magnetised and using magnetic particles to see indications of, for example, cracks. The material must be clean and unpainted.
- Eddy-current testing – Is based on principles of magnetic induction and, in brief, involves an instrument measuring changes in the electrical and magnetic properties of a material. Measurements can provide indications of superficial defects such as cracks. Can also be used on painted surfaces.

1.10 Measures in respect of the control arms on Jetline

1.10.1 Ordering and manufacture of new front control arms in 2019

During the annual inspection of train B in October 2019 cracks were detected around the tube attachment in the middle of the front control arm. The wear on the control arm in general was deemed too great for it to be repaired and renovated. Instead it was decided that the front control arms on all five trains would be replaced with new ones.

Gröna Lund chose to contact the company Mekosmos AB with a manufacturing enquiry. This choice was based on the fact that this company had been engaged for the past several years for the manufacture of other parts for Jetline and there were good experiences from this collaboration.

An email message containing an enquiry concerning the manufacture of five control arms was sent from Gröna Lund to Mekosmos in November 2019. A copy of an original drawing for the control arm was appended (see Appendix 1 with the drawing in large format). The message also stated: '*Verification of 100% covering all welds*'. According to Gröna Lund, it was understood that this expression entailed a requirement for magnetic particle inspection (testing in order to detect superficial defects) of all welds.

No other requirements in respect of the manufacture of the control arms were specified by Gröna Lund. The person who placed the order has stated that it was Gröna Lund's understanding that there were no specific regulations that applied to manufacture. No other expert within the field was engaged or consulted about how the supporting documentation in the order should be formatted. According to Gröna Lund, the drawing contained sufficient information in order to specify the measurements, welding procedure and other relevant specifications.

The drawing showed how the welds in the joints between the square tubes in the control arms were to be formed. What was specified were measurements and angles for the ends of the tubes and that the welds were to be executed as butt welds. Butt welding involves the material being welded together end to end with a certain distance between the ends and a certain angle between the edges of the ends. At the joints closest to the middle of the control arms, the welds were to be executed in a root gap of 5 mm between the square tubes and with the edges of the tubes at an angle of 15 degrees (see Figure 24). The butt weld was also to have an even surface and a smooth transition towards the material that is welded together.

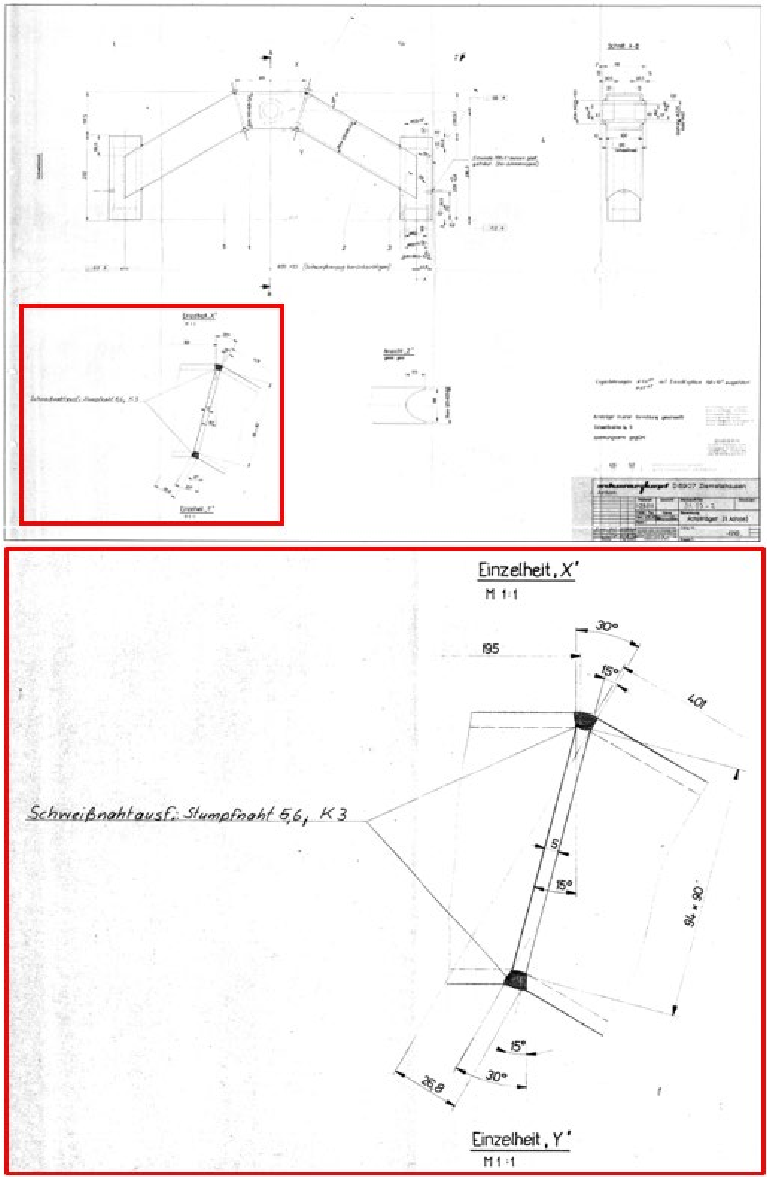


Figure 24. The entire drawing of the control arm from the order in 2019 is shown above. The image below shows an enlargement of the area in the square marking on the drawing. The measurements and infill (the black infill) for the weld in the joints in the square tubes closest to the middle of the control arm. The German word Einzelheit on the drawing means detail. Drawing from Gröna Lund (Appendix 1).

Mekosmos did not perform welding themselves and therefore forwarded the order with the email message from Gröna Lund to Göteborgs Mekaniska Werkstad AB (GMW). Gröna Lund was not informed that the work had been put out to a subcontractor.

GMW drew up a quotation for Mekosmos in which it specified the tube material, labour elements and '*verification with 100% crack indication*'. According to GMW's quotation for Mekosmos, the crack indication was to be performed by the company AB Materialröntgen i Göteborg. Mekosmos sent a quotation based on GMW's quotation to Gröna Lund, which placed an order on the basis of this quotation in December 2019.

GMW bought the material that was then processed and checked by the staff who performed the work. According to information from the person who welded the control arms, there was uncertainty about the execution of the work, which is why the person who dealt with the order at GMW was consulted. The uncertainty concerned how the joints were to be welded, whether or not there was to be a backing bar (material instead of empty space at the base of the joint that was to be welded). Their joint assessment was that there was not to be a backing bar there. No other actions were taken in order to ensure this was the procedure. The welder who performed the work had neither a formal welding qualification nor a valid welder qualification certificate ('weld licence'). However, he did have a lot of experience of welding various materials.

Once GMW had manufactured the control arms in January 2020, they were sent to the company Materialröntgen i Göteborg AB for magnetic particle inspection. The testing did not show any defects and the control arms were forwarded to Mekosmos ahead of their delivery to Gröna Lund.

Produktspecifikation/Object: **Sprickindikering av 5st Axelhållare till Gröna Lund.**
Ritn. nr./Drwg. No.: **S25C-919111510420** Rev./Rev: **--**
Kontrollplan rev./Insp. plan rev.: **---** Rev./Rev.: **---**
Materialkvalitet/Quality: **Kolstål**
Datum för provning/Date of test: **2020-01-14**
Provytans tillstånd/Surface condition of test specimen: **Acceptabel/Rengjord**
Temp./Temp.: **15 °C**
Värmebehandlad/Heat treated: ☐ **Ja/Yes** ☒ **Nej/No.**
Provningsplats/Place of testing: **MR lab**
Provning enligt/Examination acc. to: **EN-ISO 17638** Rev./Rev: **2016**
Acceptanskrav enl./Accept. standard acc. to: **EN-ISO 23278, Nivå 1** Rev./Rev: **2015**
Teknisk Instr./ Techiqual instruction: **MR TI 9.2.2** Rev./Rev.: **9**
Provningsomfattning/Extent of testing: **100% magnetpulverprovning av svetsfogar enligt produktspecifikation ovan.**
Övrig information/Supplemantary information: **Svetsmetod: 135** **Tillsatsmaterial: IT-SG3**
Använd utrustning/Used equipment: **Ferrous, S.no: 13262** MR nr./MR No.: **MR-53**
Strömstyrka/Amperage: **--- A**
Magnetpulver/Magnetic powder: **Pfinder 251** Ch. Nr./Ch. No.: **L26826**
Kontaktavstånd/Prod spacing: **100-125 mm**
Lyftkraft/Lifting power: **4,6 Kg**
Bärvätska / Carrier fluid: **Fotogen**

☒ 1 Polmagnetisering/ Pole magnetization
- ☒ 1 Okmagnitesering/ Yoke magnetization
- ☐ 2 Spolmagnetisering/ Coil magnetization

☐ 2 Strömgenomflytning Current flow method
- ☐ 1 Ström genom provföremål/ Current through test specimen
- ☐ 2 Ström genom hjälpledare/ Current through auxiliary conduktor
- ☐ 3 Induktion i provföremål/ Induktion in test specimen

☒ 1 Växelström/ A.C.
☐ 2 Permanentmagnet/ Permanent magnet
☐ 3 Likström/ D.C
☐ 4 Strömstöt/ Current flash
Varvtal/Numb. of turn: ---

☐ Torra metoden Dry method
☒ Våta metoden Wet method
☒ Kontrastfärg använd/ Contrast aid used
☒ Svart Black
☐ Röd/Red
☐ UV ljus / UV light
☐ Fluorescerande./Fluorescent
Pulverkoncentration/Powder koncentration: ☒ Normal/Normal ☐ Annan/ Other -- %

Avmagnetisering/Demagnetization: ☐ **Ja/Yes** ☒ **Nej/No**
Restfält uppmätt/Residual magnetism checked: ☐ **Ja/Yes** ☒ **Nej/No**
☐ Magnetiseringen kontrollerad med flödesindikator/Magnetization checked by flow indicator. Max värde/ Max value: **--- T**

Uppfyller krav enl. spec./Acceptable acc. to procedure ☒ **Ja/Yes** ☐ **Nej/No**

Provningsresultat/Test result

Utan anmärkning.
Uppfyller krav enligt standard.

Figure 25. Excerpt from the record of the crack indication check of the control arms that was ordered from the company Materialröntgen i Göteborg AB.

The control arms were delivered to Gröna Lund in early spring 2020. According to Gröna Lund, the delivery was received without conducting any details checks because the control arms were to be checked before being mounted to the trains. During SHK's visual examination of the control arms, damage was noted around the centre hole in the middle of one of them. This damage was underneath the painted surface and was therefore deemed to have occurred at the time it was manufactured (see Figure 26). The control arm was found where the others that were supplied in 2019 were being stored, but Gröna Lund stated that it was to be scrapped.

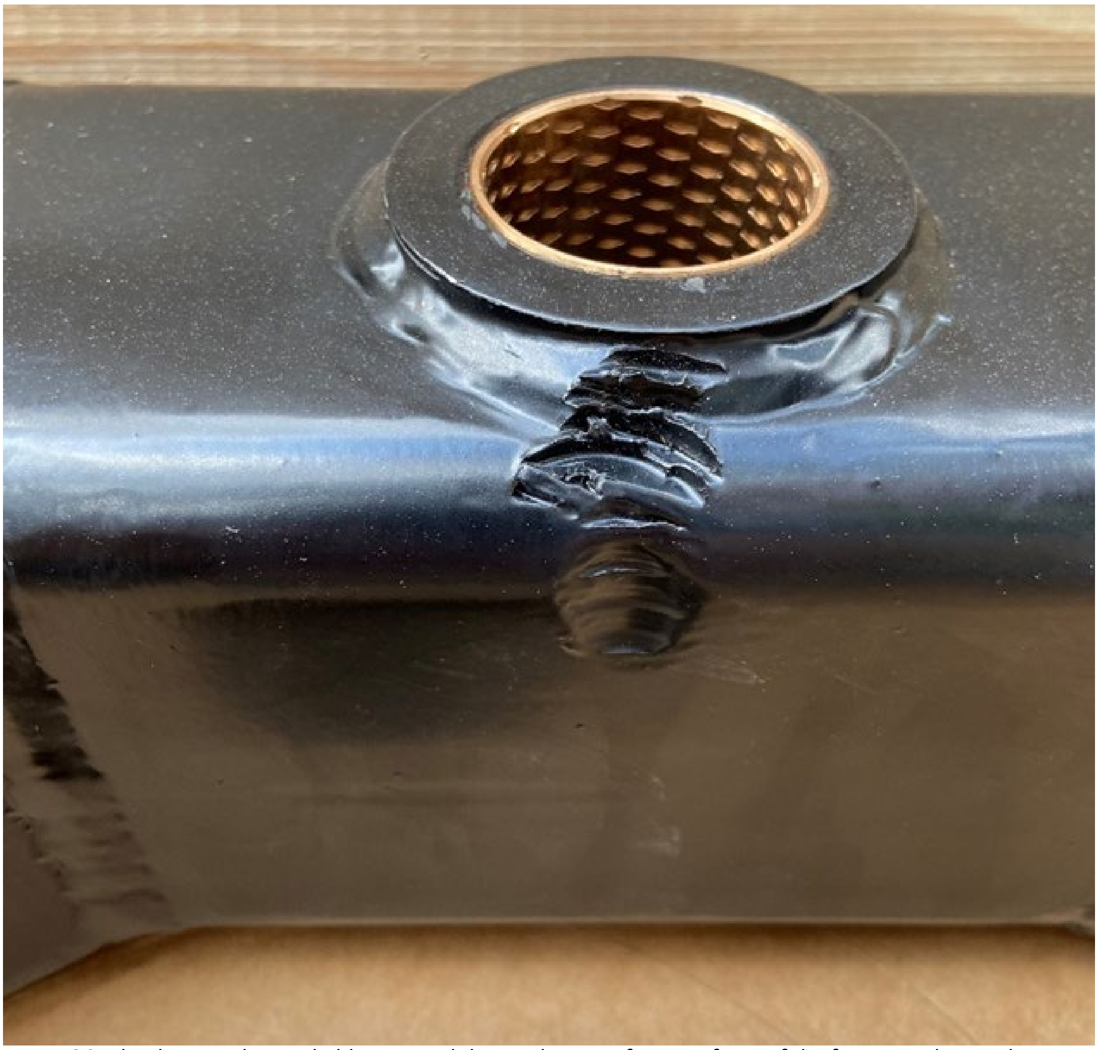


Figure 26. The damage that probably occurred during the manufacture of one of the five control arms that was supplied in 2019.

1.10.2 Ordering and manufacture of rear control arms in 2022

On 28 August 2022 it was noticed that one car in train E was not aligned with the other cars. The train was taken out of service immediately and a crack was discovered in the rear control arm on the first car (original control arm from 1988). The crack had appeared in the wall of the square tube (see Figure 27).

Figure 27. The crack that was discovered on 28 August 2022 in an original rear control arm from 1988. Photo: Gröna Lund AB.

Gröna Lund closed Jetline immediately in order to check the control arms on all trains that had been in service (B, C, D and E). DEKRA conducted eddy-current testing on all the control arms that were installed on the trains at that time. In addition to the crack in the wall, the testing of the welds showed that there were cracks in the welds on two rear control arms on trains C and D, but no defects in the front control arms.

According to Gröna Lund, an inspection expert from DEKRA was consulted about how best to rectify the cracks, after which the cracks were welded by staff at Gröna Lund. The welds were performed by licensed staff at Gröna Lund and under the supervision of DEKRA. After welding, DEKRA conducted magnetic particle inspections which showed no anomalies. The work was completed in September 2022 and trains B, C and D were put back into service. Gröna Lund decided that new rear control arms would be ordered for all trains and train E was not used while waiting for these.

New rear control arms were ordered from Mekosmos in autumn 2022. Gröna Lund also sent a copy of the original drawing (see Figure 28) with this order. Manufacturing was subcontracted to GMW by Mekosmos in the equivalent manner to when the front control arms were ordered in 2019. Gröna Lund was also not informed this time that the work had been put out to a subcontractor. However, GMW did not have the capacity to deliver this order and therefore put out the work to yet another subcontractor.

An initial delivery of 15 rear control arms was made to Gröna Lund in March 2023. A visual inspection by staff at Gröna Lund showed that the control arms had not been manufactured correctly. Among other things, certain measurements were not consistent with the drawing and the welds were deemed to have anomalies. The control arms were sent back to the supplier in order to be scrapped and with the instruction that new ones be manufactured. The manufacture of new control arms took a long time and none of these control arms were installed on any train.

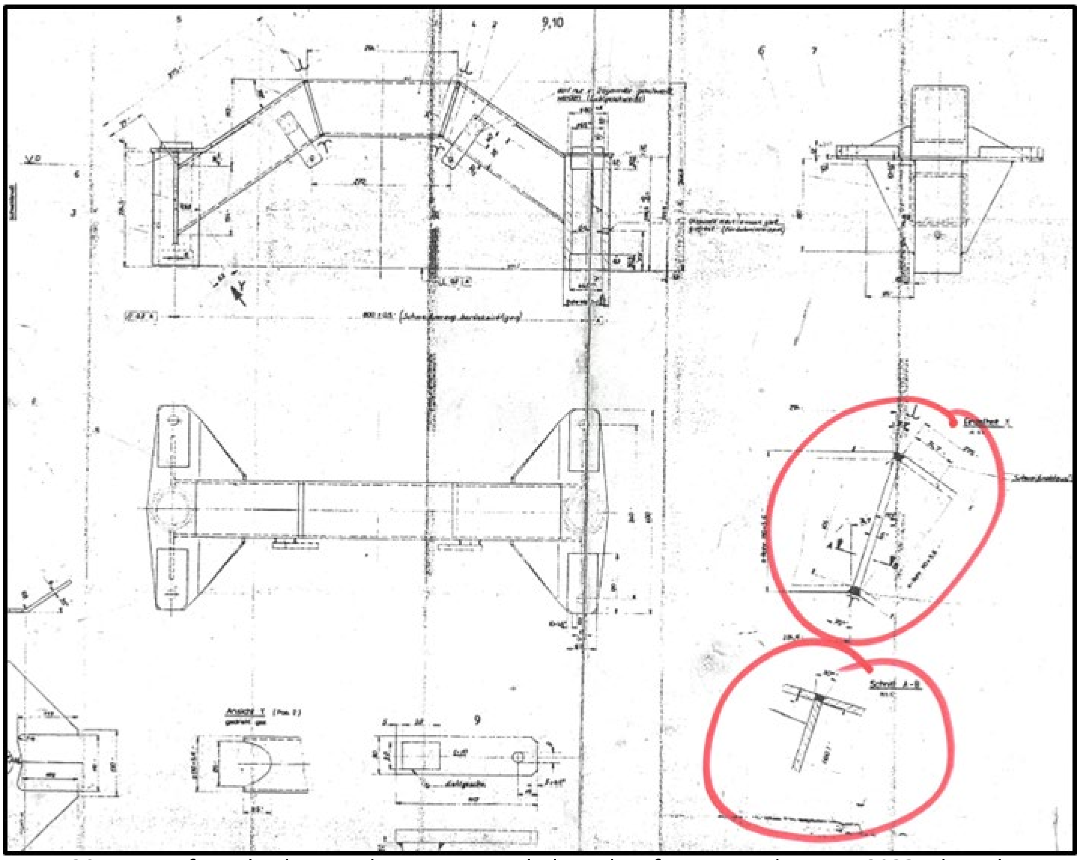


Figure 28. Excerpt from the drawing that was sent with the order of rear control arms in 2022. The red rings have not been drawn in by SHK but the outside of a joint in the control arm is shown in more detail in the upper ring and a cross-section (the inside) of the joint is shown in the lower ring. It can be seen in the cross-section that there should be material on the inside of the joint where the parts are to be welded together.

1.10.3 Repairs to cracks on rear control arms

According to information from Gröna Lund, small superficial cracks in welds on the rear control arms had been identified during inspections in various years. According to Gröna Lund, an inspection expert from DEKRA was consulted about how best to rectify the cracks and the cracks were welded together by the amusement park's own licensed welder under the supervision of DEKRA (see Figure 29). The non-destructive testing that was ordered following the repairs did not show any superficial defects. No other checks, for example revision inspection, were ordered in conjunction with the repairs.

The welding repairs were not registered in any logbook or service record but number and year had been registered in another way, including in DEKRA's testing record. It is reported that twelve cracks were welded and checked between 2006 and 2023.

Figure 29. Weld repair on a control arm marked with a red ring. The photo is of a control arm installed on train C. The weld repair is on the weld between the outer and middle parts of the control arm.

1.10.4 Installation of and checks on control arms after 2019

One of the five newly manufactured control arms was installed on train B during the winter of 2020. However, because of the restrictions during the coronavirus pandemic, the train was not put into service until 2022. The control arm that broke in conjunction with the accident was installed on train E in March 2023. The other three control arms were not installed on any trains prior to the accident.

The front control arm on train E (the train involved in the accident) was installed when the train had been taken out of service following the detection of the crack in a fixed control arm in August 2022 (see section 1.10.2). The intention was also that the rear control arms would be replaced with newly manufactured ones but this was postponed due to defects in those that had been delivered. Instead, the rear control arm with the crack was replaced with another original control arm from 1988.

In February 2023 DEKRA conducted eddy-current testing of the bogies on the rear control arm where the crack had been detected in August 2022. No cracks were detected during the test and the bogies were mounted on the control arm that had replaced the control arm with the crack. Later that spring, eddy-current testing was conducted on all the control arms on train E and also on train B, which also had a front control arm from 2019. No defects were detected during the tests.

No more extensive checks or tests were conducted, for example through a revision inspection. Nor was there any requirement to conduct a revision inspection in regulations or standards if the parts that had been replaced were equivalent to the original parts.

After the replacement and the checks on the control arms, annual maintenance was conducted on the whole train in accordance with a checklist. This work was completed at the beginning of April and train E was brought into service on 26 April 2023. Over the period up to the accident, the checks that were to be conducted daily, weekly and monthly were conducted up to the date of the accident.

1.11 Accidents and actions in some other similar rollercoasters

1.11.1 Lisebergbanan

Lisebergbanan at the amusement park Liseberg in Gothenburg was manufactured in 1987 by the same company that manufactured Jetline. Both the tracks and the cars had similar constructions but the tracks were differently shaped. The lap bars were of the same type and construction.

During an accident in 2006 the lift chain (the chain that pulled the train up the first hill) broke and the anti-rollback dogs did not stop the train from rolling backwards. After having rolled down to the boarding area, it crashed into a waiting train. Twenty-one people sustained minor injuries. The anti-rollback dogs had been altered in order to reduce noise during the ride but instead did not have sufficient friction as they had been equipped with a plastic covering. In turn this impaired the function of the anti-rollback dogs.

The accident was investigated by SHK *(RO 2007:03)*. The investigation showed that Lisebergbanan was inspected and approved in accordance with the regulatory system applicable at the time, which included inspections by an accredited inspection body. In addition to this, Liseberg’s own rules stipulated that the function of the anti-rollback dogs had to be checked every day in the workshop. In spite of the inspections conducted by the inspection body and Liseberg’s own checks, the functional defect with the anti-rollback dogs was not detected. The rollercoaster was repaired following the accident and the plastic covering was removed. The rollercoaster was subsequently inspected and approved by the inspection body.

According to the investigation, the cause of the accident was a lack of procedures that enabled the identification of risks associated with, and the defective function of, the remodelled anti-rollback dogs.

The investigation pointed to the lack of explicit regulatory requirements concerning organisation, methods, safety management and what should be included in an in-house check. Consequently, SHK therefore recommended the then National Police Board to take action for a review of the legislation concerning amusement rides and consider amendments to the National Police Board’s regulations concerning inspection of amusement rides (RPSFS 2002:25, FAP 513–1). As a consequence of the recommendations the then National Police Board introduced some amendments and addenda to the regulations.

1.11.2 Mindbender, Quimera and Knightmare

Mindbender, Quimera and Knightmare are three further rollercoasters from the company Schwarzkopf that built Jetline. Unlike Jetline, Mindbender and Quimera had loops in their tracks. The basic construction of the trains used on these rollercoasters was similar to that of those used on Jetline. SHK's scrutiny of available information about these rollercoasters has been focussed on the design of the safety devices that restrained the passengers during the ride.

There have been fatal accidents on Mindbender and Quimera. According to available information, the accidents have involved faults with the wheel assemblies – but with substantial differences compared to the accident at Gröna Lund. For these accidents faults in inspection procedures and technical measures are described as the reasons why the wheel assemblies came off.

Mindbender

The rollercoaster Mindbender was installed in Edmonton, Canada in 1985 and was taken out of service in 2023.

An accident in 1986 involved four people falling out of the last car in the train after a wheel assembly had come off and the car had derailed. Three people died and one was seriously injured. Incorrect mounting of screws has been specified as the cause of the occurrence. The lap bars, which were constructed in the same way as those on Jetline, were not able to keep the people in the cars in conjunction with the accident.

The attraction was reopened after a number of modifications were made. The passenger restraint function of the cars was redesigned and the lap bars were supplemented with a safety belt and a back support with yokes that were lowered over the passengers' shoulders.

Quimera

Quimera was a rollercoaster in Mexico City from 2007–2019. The cars in the train had space for four people. Available pictures indicate that the restraints in the cars consisted of a lap bar similar to that on Jetline but supplemented with two belts over the passengers' shoulders.

The rollercoaster closed following an accident in 2019 in which two people died and two were seriously injured. Faulty screws and spare parts resulted in a wheel assembly on the last car coming off, causing the car and its passengers to fall to the ground. Subsequent examination of the track also found cracks in various train parts and in the track structure. The train may also have been running too fast without braking control.

Knightmare

Knightmare was a rollercoaster in Chorley, United Kingdom from 2007–2012. A review of video material from the track shows that the lap bars were of the same type as those on Jetline but the bars were supplemented with a safety belt over the passengers' shoulders.

1.12 Other organisations concerned

Swedish Association for Testing, Inspection and Certification (Swetic)

Swetic is a trade organisation for companies active in testing, inspection, verification, calibration and certification. The association is made up of over forty companies, all of which are accredited by the public authority Swedac. The association runs training programmes and deals with, among other things, industry-specific questions in technical committees.

During the investigation, Swetic has disclosed that the Swedish Police Authority previously participated in consultation meetings that take place with the industry and the accreditation body (Swedac). At these meetings it was possible for consultation to take place relating to current rules in the field and a summary was provided of incidents that had occurred. The Swedish Police Authority has not participated in consultations since at least 2017. There is a strong desire from the industry that consultation with the Swedish Police Authority be resumed.

International Association of Amusement Parks and Attractions (IAAPA)

Since 1918, the IAAPA has been a worldwide trade organisation for amusement parks and manufacturers of attractions, with its head office in Orlando, USA. The organisation holds events and conferences in various segments such as safety. Gröna Lund is a member of the organisation.

International Organization for Standardization (ISO)

ISO has existed since 1964 and is an independent, non-governmental organisation with members from national standardisation bodies in 171 countries. Its work on standards is conducted in committees for various areas.

European Committee for Standardization (CEN)

CEN is an independent, non-governmental standardisation organisation that is recognised by the EU and EFTA and has 34 member states that are represented by their standardisation bodies. CEN brings together experts in technical committees in order to produce and revise European standards.

Swedish Institute for Standards (SIS)

SIS is a non-profit association appointed by the Government as the Swedish standardisation body and is part of ISO and CEN. Its work to produce standards is conducted in technical committees, participation in which is open to all legal entities in Sweden.

1.13 Actions taken

1.13.1 Gröna Lund

As a result of the accident, a change process has been initiated at Gröna Lund and part of this has involved a consulting firm being engaged for the purpose of improving and strengthening its safety work. In addition to changes in the safety work in general, more specific measures have been described.

- A new verification plan for the process of ordering spare parts with a checklist for, among other things, various checks and technical consultation ahead of the request for quotations.
- An updated ordering and delivery procedure, order form, delivery checks and checks of suppliers of spare parts linked to SS EN 13814–1:2019, ISO 9001 and EN 1090–2.
- Classification of spare parts on the basis of a safety perspective began in 2024. However, the work on this classification has been applied to all new spare parts orders since the end of 2023.
- A new documentation procedure for the attractions in order to clarify and quality assure digital storage of documentation in accordance with the description in SS EN 13814–1,2,3:2019.
- A new digital system for servicing and inspection of attractions.

Please refer to Appendix 2 for a more extensive description of the actions taken by Gröna Lund.

1.13.2 Swedish Police Authority

During the investigation, the Swedish Police Authority has stated that the limited inspection function that takes place in conjunction with considering applications for authorisation under the Public Order Act means that activities relating to amusement rides are of no or, in any case, low relevance to the police. According to the Swedish Police Authority, current procedures should be revised as part of the effort to streamline the Police Authority’s operations.

The Swedish Police Authority has already identified a need for a revision of the regulations and such work has begun. The responsibilities, roles and assignments of the parties concerned will be clarified within the scope of this revision. Furthermore, references to the standards will be updated and exemptions from the regulations will be reviewed.

2. Analysis

2.1 Prerequisites and orientation

The investigation shows that the newly manufactured front control arm on one of the cars on the rollercoaster broke and that, as a result, the train's chassis hit the joints in the track. This led to sharp decelerations. In conjunction with the sharp decelerations, the passengers were pressed with such a great force against the lap bars that the lap bars were bent forward towards an open position. Three of the passengers fell out of the train, one person died and others suffered serious injuries.

The aim of the analysis is to identify which circumstances during ordering, manufacture and inspections have contributed to a control arm with insufficient strength being used. In addition, the analysis aims to answer the question of why the lap bars did not keep all of the passengers in the train when the accident occurred.

The analysis touches on supervision, regulations, standards, checks, inspections, Gröna Lund's safety work and procedures and working practices at the subcontractors concerned.

The aim of the analysis is also to identify which measures to improve safety should be implemented in order to reduce the risk of similar accidents occurring at amusement parks in the future in both Sweden and internationally.

2.2 Why was it possible for the control arm to break?

The control arm was newly manufactured but deviated from the original construction through the lack of transverse metal plates inside the control arm. There were also serious welding defects in the weld joints. This resulted in insufficient strength. The forces that arose when the train was run on the track were sufficient for the weld joints to fail.

2.2.1 Ordering

Cracks in a front control arm of one of the trains on Jetline were detected in conjunction with an annual inspection in 2019. Due to there also being major wear and tear on the control arm, Gröna Lund decided that the control arms on all five trains would be replaced with new ones (see section 1.10.1). The order was placed with the company Mekosmos, with which Gröna Lund had a long-standing business relationship. Mekosmos put out the manufacturing work to a subcontractor (GMW).

The strength of the control arms was totally vital to the safety of the attraction. Consequently, maintaining the original safety level of the rollercoaster required the new control arms to have equivalent properties and specifications to the original ones. This placed major demands on Gröna Lund to ensure the order was formatted in such a way that it was possible to manufacture and supply a product that was consistent with the properties and specifications of the original control arms.

Essential parts of the drawing that was appended to Gröna Lund's order lacked a detailed description of how it was to be executed. There was no cross-section in the drawing that described from the inside the parts that were to be welded together. The implications of this included that there was no description of the transverse metal plates that were in the original control arm and which were of significance to the torsional stiffness of the structure and which also functioned as backing bars for the welds. The drawing did not indicate whether the welds were to be executed using a backing bar or whether there was just to be a root gap where the sections of tubing were welded together. The part that was enlarged on the drawing and which was labelled ‘Einzelheit’ (German for detail) only depicted parts of the outside of the control arm in more detail.

Nor was there any other information which specified that there was to be transverse metal plates inside the control arm or a general description of the inside of the structure.

When the order was placed, no reference was made to the requirements in applicable standards for amusement attractions (SE-EN 1384:2019), among other things about the specific procedures that are to be applied when welding an amusement attraction or the requirement that the person performing the work have a welder qualification certificate.

There were no specific procedures or internal policy documents at the amusement park that described how orders of replacement parts were to be placed in order to ensure the consistency of the parts with the originals.

All in all, Gröna Lund’s order was marred by serious deficiencies both in terms of the lack of vital parts of the drawing and through it not specifying which standards were to be applied during manufacture. Nor were the deficiencies noticed in the stage in which the order was put out to a subcontractor. These circumstances had a direct impact on how the new control arms were produced and the strength of the structure.

2.2.2 Manufacturing

Accordingly, Gröna Lund’s order was marred by serious deficiencies. In addition to this, however, there were anomalies in the workmanship that were directly attributable to the manufacturing itself. The tube parts had not been processed in a way that was consistent with the drawing and the welds also had extensive lack of fusion (insufficient fusion of the material) as well as irregularities that could cause cracks (see section 1.6.3).

The likelihood of executing an even weld with more extensive fusion was reduced through no backing bar being used when welding. As described in section 2.2.1, Gröna Lund did not provide any supporting documentation for assessing whether the weld was to be executed with or without a backing bar. Consequently, the only information in the order documentation – the drawing – led to uncertainty about how the welds were to be executed on the part of the person who was to do the work. This matter was discussed internally within the company GMW but no contact was made with Mekosmos regarding how this part of the order was to be interpreted. This and the defective welding contributed to the low strength of the structure.

2.2.3 Checks

Checks during manufacturing and upon delivery

It is evident from the investigation that the welds in the new control arms ordered by Gröna Lund were to be checked by means of magnetic particle inspection before being delivered to the amusement park. No defects were detected during these checks, which took place before they were delivered to Mekosmos. However, the testing method was not able to indicate any anomalies inside the structure. No additional checks or actions were implemented by either GMW or Mekosmos in order to ensure that the control arms complied with the requirements set out in Gröna Lund’s order.

Nor did any more detailed checks take place once the control arms had been delivered to Gröna Lund. According to Gröna Lund, the staff who received the delivery did not have the expertise to check and were not tasked with checking for any deficiencies in the welds in terms of their appearance or other aspects of their execution. The damage in the wall of one of the control arms was therefore not detected (see Figure 26). According to Gröna Lund, the intention was not to check the control arms at the time of their delivery, instead this was to be done when they were to be installed. The damage to one of the control arms was, however, very visible and could have given Gröna Lund an indication that there were issues with the quality of the manufacturing.

After front control arms from 2019 had been installed on trains B and E (the train involved in the accident) eddy-current tests were performed in spring 2023 on all control arms before the trains were put into service. The tests did not show any anomalies but it was also not possible using this testing method to identify internal cracks or anomalies in the structure.

The intention was for the new control arms to have the same specifications and properties as the original ones, i.e. for them to be what are known as replacement parts. Consequently, the installation of the control arms did not entail any requirement for a revision inspection in accordance with the Swedish Police Authority's regulations and general advice FAP 513–1 (Section 11).

Nevertheless, under the applicable standards for amusement attractions, to which the Swedish Police Authority's regulations refer, replacement parts have to be consistent with the original. The person or company who is responsible for the ride therefore needs to ensure that the parts that are replaced have the correct specification. The checks that were conducted during manufacturing and before the control arms were brought into use were not sufficient to detect the faults. Additional checks on the part of Gröna Lund would have been required in order to ensure that the structure was safe.

Inspections

As described in section 1.10.1, a new front control arm had been installed on another of Jetline's trains as early as 2020. After this, annual checks of the entire attraction had taken place without the faults being detected, most recently in January 2023.

Section 4 of the Ordinance on Inspection of Amusement Rides states that the inspection body shall, during the inspection, not only verify that the attraction has been implemented in a manner that is consistent with applicable regulations but also which is otherwise satisfactory from the perspective of safety. The requirement for verification measures is thus not limited to that which is explicitly specified in the regulations (FAP 513–1). If there are indications of deficiencies in terms of safety, additional verification measures may be necessary in order for the attraction to be approved.

The inspection company that performed the inspections and tests on Jetline (DEKRA Industrial AB) was not informed by Gröna Lund that control arms had been replaced and nor was this a stipulated requirement. The replacement of control arms was also not entered in the record (the log) for the attraction. The supporting documentation and the information that was available to the inspection company at the time of the inspections did not give any other indications of any faults.

Consequently, with the current inspection requirements formatted in the way they are, there were limited opportunities for the inspection company to detect the faults in the control arms during the recurring inspections. This matter is addressed in more detail in section 2.4.

2.3 Gröna Lund’s safety work

The work involving the technical safety of the attractions at Gröna Lund was largely focused on the stipulated daily and recurring checks and associated inspections. The measures were based primarily on checklists and manuals for the individual attractions, and their implementation was ensured through training courses for staff. Anomalies identified in the attractions, for example wear and damage, were rectified continually through parts being replaced or repaired. At the end of a season, there were meetings at which experiences from operating each attraction were discussed. This then formed the basis of deciding on action and investment requirements for individual attractions.

The recurring checks and inspections appear, in all material respects, to have been implemented in accordance with the stipulated requirements. The investigation has not demonstrated any failings when it comes to the periodicity or scope of the stipulated checks on Jetline. Nor have any deficiencies emerged with regard to the daily technical checks or the expertise or experience of the staff for these duties.

There were checklists and follow-up systems for the recurring checks. However, there were no documented procedural descriptions and internal policy documents for other aspects of the safety work in respect of the attractions. This has made it difficult for SHK to establish a clear picture of the safety work that was conducted alongside the direct actions involving the individual attractions. SHK has had to rely on verbal reports from the responsible managers and an organisational outline that was produced after the accident.

Gröna Lund’s safety work relating to the attractions prior to the accident was based on identified defects that had arisen and incidents that had occurred. No methodology, for example risk analyses, for identifying and managing accident risks in the attractions other than those that could be directly observed has emerged. The deficient procedures for supplier orders are an example of this. Nor have faults that have arisen in the attractions been analysed from a wider safety perspective. For example, no specific conclusions were drawn about the safety of Jetline based on the cracks that were detected in the rear control arms as early as 2006 and subsequently on several occasions up to 2023. The cracks were repaired but there were no deliberations about why the cracks had arisen or what the implications of the cracks might be for the safety of Jetline. Nor was any assessment made about whether the cracks could indicate other hidden faults in the control arms or whether the repairs had a detrimental impact on strength. Nor was there any system on Jetline for adapting checks, maintenance measures or limitations on use in line with increasing age and operating time.

The investigation shows that when the control arms were ordered sufficient requirements were not set with respect to how they were to be manufactured and the manufacturing process itself. Nor were sufficient inspections conducted of the workmanship after they had been delivered and before they started being used. The safety work conducted at Gröna Lund did not result in adequate accident safety on the rollercoaster.

The deficiencies described suggest that there was no comprehensive view of the risks and fixed and established method at the amusement park for identifying, assessing and managing risks associated with operating the attraction. At a systemic level this became a contributing factor to the accident.

Gröna Lund has described a large number of ongoing improvements relating to the safety of the attractions that are important parts of a systematic approach to safety work. The measures described appear relevant but have not yet been fully implemented in the organisation. Gröna Lund is therefore recommended to draw up and implement safety work for its attractions which ensures that:

- risks in the form of organisational and technical failings that may lead to accidents are continually identified, analysed and rectified.
- procedures are drawn up which ensure that replacement parts comply with the requirements originally set for the attraction in question,
- checks are tailored to the operating time of an attraction and identified risks,
- the entirety of the safety work is frequently followed up, evaluated and, when necessary, revised.

2.4 Vague regulations

2.4.1 Introduction

The fundamental safety requirements placed on the operator of an amusement park are set out in the Public Order Act. This states that only amusement rides that provide satisfactory accident safety and have been inspected may be provided to the general public. The Ordinance (1993:1634) on Inspection of Amusement Rides and associated regulations and general advice in the National Police Board's FAP 513–1 contain more detailed provisions concerning inspections etc. Under the systematic approach described in these rules, amusement attractions have to both provide satisfactory accident safety and be inspected in the manner specified in more detail in legislation and regulations. It is the operator that is responsible for the safety of the attraction and for ensuring that the stipulated inspections take place.

Jetline was inspected and approved at the stipulated annual inspection in January 2023. However, the accident demonstrates that the requirement for satisfactory safety was not met at the time of the accident. The question is whether the regulatory framework provided sufficient opportunities to capture relevant safety aspects in the facility.

2.4.2 Amusement park and funfair companies' responsibility for safety needs to be highlighted more clearly

The Ordinance on Inspection of Amusement Rides and FAP 513–1 place a great deal of emphasis on checks and inspection of attractions. There are detailed provisions about what is to be checked and at which intervals. Naturally, there are good reasons for this. Regular checks of safety-critical components contribute to enabling damage or anomalies to be detected and rectified on time.

At the same time, there is a risk that faults or damage that arise between inspections are not identified and dealt with. At least not if the nature of the fault is such that it cannot be detected during more general checks that take place on a daily basis. It was not possible to detect the anomalies that were found in the front control arms manufactured in 2019 during superficial checks. There were limited chances of detecting these during the recurring checks. The stipulated inspection measures also do not take into account the operating time of the attraction. This means there is a risk that the increased risks of material fatigue that may be associated with advancing age and use will not be caught. Regular checks and inspections alone are thus not sufficient to ensure the safety of an amusement attraction.

On top of this, the provisions in the ordinance and FAP 513–1 give the impression that they are primarily directed at the inspection body. At the same time, the inspection body is entirely dependent on the operator ordering inspections and tests. If no orders are placed, it is not possible for the inspection body to take action independently.

One consequence of the strong focus on the inspection body is that this risks obscuring the operator's responsibility for safety. This applies both to overall responsibility for the safety of the attractions and responsibility for implementing additional measures and checks that may be necessary in order to maintain a sufficient safety level and for ensuring the technical integrity of the attraction over time. This is especially relevant for older attractions where material fatigue and similar anomalies may occur. As has emerged, material fatigue on Jetline's rear control arms was discovered as early as 2006, which was dealt with through ongoing repairs at Gröna Lund.

There is much to suggest that Gröna Lund regarded the Swedish Police Authority's regulations (FAP 513–1) as the primary policy document governing the safety of its attractions. To a lesser extent, the activities and the risks have been analysed on the basis of the general requirements placed on the operator by the Public Order Act. This may potentially explain the lack of a comprehensive view of the risks and the lack of quality-assured processes when ordering and checking replacement parts.

As early as the investigation into the accident involving Lisebergbanan in 2006, SHK established there was a risk of the companies concerned relying solely on the technical inspections conducted by the inspection body. This is a position that is still justified. Consequently, the rules need to be adapted so that they, more clearly than is currently the case, state that it is the operator who is responsible for the safety of the attractions and is obliged to take whatever action is necessary in order to ensure the attraction has satisfactory accident safety.

2.4.3 Checks on replacement parts

The applicable standards for amusement attractions, to which FAP 513–1 refers, state that replacement parts shall be consistent with the original. However, neither the regulations nor the standards contain any specific requirements for inspection after replacement parts have been installed in an attraction. As described above, it is instead up to the operator to take the action that is necessary in order to ensure the attraction provides satisfactory accident safety. This can be done through, for example, a revision inspection or other similar checks.

As described in section 2.2.3, the checks that were performed were not sufficient to prevent control arms with defective workmanship and insufficient strength from being installed and used on the trains. The uncertainties relating to division of roles between amusement park and funfair companies and the inspection body with respect to responsibility for ensuring that sufficient checks are implemented may also have played a part here.

According to SHK, the requirements for inspection measures should be supplemented so that these also encompass checking that the attraction has not undergone alterations or interventions that may affect the safety of the attraction. These checks should take place in conjunction with the recurring annual inspections and if any alteration has been made, for example replacement of parts that are vital to safety, this should result in more extensive checks. Furthermore, the general advice concerning record-keeping should be supplemented so that the record for each attraction states what maintenance measures, alterations or interventions have been implemented on the attraction. An appropriate way to format these rules is to use those that apply to lifts and certain other motorised devices (see section 1.7.5) as a model. In these both the inspection requirements and the record-keeping rules are more comprehensive than those that apply to amusement attractions.

2.4.4 Summary of the need for regulatory changes

It is the opinion of SHK that there is a risk that the regulations' strong focus on technical checks and inspections leads to reactive safety work at the expense of a comprehensive view of the risks that may be associated with the facility. Consequently, amusement park and funfair companies' responsibility for the safety of the attractions needs to be highlighted more clearly and the need for a systematic approach to safety work needs to be reflected in legislation.

A change in this direction does not negate the fact that there is a need to supplement the rules on recurring checks. Specific requirements for checks and inspections should be introduced in order to ensure that an amusement attraction has not been subject to alterations or interventions that may reduce the safety of the attraction. The general advice concerning record-keeping should be supplemented so that the record for each attraction also states what maintenance measures, alterations or interventions have been implemented on the attraction,

Finally, it should be made clear that the requirements concerning operation and maintenance in applicable standards also encompass amusement attractions manufactured prior to 1 July 2006. The existing references to applicable standards need to be updated.

On its own initiative, the Swedish Police Authority has begun working on a review of the regulations (FAP 513–1). It is vital that this work continues and is completed. The Swedish Police Authority is therefore recommended to conduct a review of the regulations concerning amusement rides in accordance with what is described above. If the review leads to the Swedish Police Authority making the assessment that sufficient changes are not possible at the level of regulations, the Police Authority should hand over the matter of necessary legislative changes to the Swedish Government.

2.5 Public supervision of amusement rides is insufficient

In conjunction with a decision to authorise a public event where amusement attractions are being used, the Swedish Police Authority can inspect the attraction and issue the additional conditions that are required. In larger permanent amusement parks such as Gröna Lund, there is basically no inspection of the attractions by the Swedish Police Authority before authorisation is granted. To the extent that the potential to conduct an inspection is applied, this is done primarily to smaller travelling funfairs.

Although the Swedish Police Authority's actions in relation to amusement rides have some elements that resemble supervision, for example decisions concerning authorisation and prohibition and possibilities to inspect an amusement ride, these activities cannot be considered supervision in any meaningful sense. Essentially no independent checks are conducted. Nor are any continual supervisory measures or supervisory visits implemented. In practice, the activities that are conducted are oriented entirely towards authorisation under the Public Order Act and are limited to verifying administratively that the attraction has been approved upon inspection.

The differences are great in comparison to that which applies, for example, in the field of product safety. The aim of the product safety rules is to ensure that only safe goods and services are supplied to consumers. In order to ensure that the rules are complied with, the Swedish Consumer Agency, among others, conduct supervision and market surveillance. The supervisory authority has extensive powers at its disposal and implements continual supervisory measures that can also include supervisory visits. Within the scope if its supervision, the Swedish Consumer Agency also runs advisory activities for traders regarding how to comply with the requirements in the Product Safety Act, including through guides and information about preventative safety work. Within the scope of preventative efforts there is an emphasis on, among other things, the need for risk analyses, documentation of safety work and a coherent system for reporting incidents and accidents.

Supervision within the field of product safety does not encompass rollercoasters because the Product Safety Act requires more active use of goods or services on the part of the consumer than is the case for a person who more passively rides on an amusement attraction. However, both the Product Safety Act and the Swedish Consumer Agency's supervisory activities encompass soft play centres, highwire courses, ziplines and bungy jumps. The major differences between the supervision of, on the one hand, these activities and, on the other, amusement parks and funfairs do not appear to be justified on the basis of the accident risks that may be associated with these activities. Great heights and high speeds are often part of the experience of amusement attractions. As a result, faults and failings in these facilities can have disastrous consequences, an example of which is the accident involving Jetline.

It is not possible to prove that stronger public supervision would have prevented the accident at Gröna Lund. Nevertheless, it is still reasonable to assume that public supervision of amusement attractions as outlined above could potentially have contributed to improving knowledge and a greater chance of Gröna Lund dealing with the circumstances that become contributory factors to the sequence of events. This is especially the case for supervision that includes advice and guidance concerning preventative safety work.

All in all, the assessment is made that public supervision of amusement attractions needs to be strengthened and reach a level that is at least equivalent to that which applies under the Product Safey Act.

The Government is recommended to take action to strengthen public supervision of amusement parks and funfairs. More robust supervision should include the potential to implement continual supervisory measures and supervisory visits. The supervisory activities should also include advice and information for amusement park and funfair companies about the requirements placed on the safety of amusement attractions and how these can be complied with, for example through risk analyses and a systematic approach to safety work.

2.6 How was it possible for the people to fall out of the cars?

The lap bars were designed in accordance with the standards that applied when Jetline was built and no functional defects were detected during SHK's examination of the train involved in the accident. However, it is possible to conclude that the bars were not designed for the forces generated when the passengers were thrown forward when the train's chassis hit the joints in the track. Only one of the bars where a person had been sitting during the accident had not been bent forward.

The tension testing of the lap bars showed that a force against the bar of c. 1,400 newtons (just over 140 kg) was required for it to bend permanently. It is likely that at least this force occurred when the train hit two track joints so hard that the entire track structure shook, at which point the bar for the first person to fall out of the train bent into an entirely open position. When this happened, there was no restraint function in the car and the person fell out of the car forward, diagonally to the right.

When the train ran down the next slope at low speed, the substantial cant resulted in the two people in the last car sliding towards the side of the car. Because the car was entirely open at the side in front of the seat and the lap bar was in an almost open position, it was impossible for them to remain in the car.

The tension testing of the lap bars on Jetline shows that the force on the bars during the accident may have been around five times higher than when braking during the test runs. This indicates that the bars, with a good margin, coped with the forces that could arise, for example, in the event of an emergency stop during normal operation. However, it is a fact that the restraint function with the bars alone was ineffective in the event of an accident with more violent decelerations. In addition to the lap bar, the rollercoaster Knightmare had safety belts, and the trains on Mindbender were equipped with more extensive restraints following the accident there. It has not been possible to obtain any data about the dimensions of the restraints there, but it is possible to conclude that the devices used to restrain the passengers were more extensive.

In the present case a more extensive system for restraining the passengers would probably have prevented them from falling out of the train. Consequently, there may be reason to consider whether the restraint of passengers on rollercoasters should also be designed for forces greater than those that can arise during normal operation, for example in the event of an accident. There are no such requirements in any of the standards that were applicable at the time Jetline was built or up to the point at which this investigation was completed.

A change in requirements in a standard requires stakeholders from the industry concerned to work on the matter within the standardisation bodies CEN or ISO. The IAAPA is therefore recommended to disseminate SHK's final report to its members and in its safety forums in order to provide members with evidence upon which to assess whether there is a requirement to alter requirements for restraint devices for rollercoasters. When providing such information, the observations in the report about the need for a systematic approach to safety work and the use of replacement parts in rollercoasters should also be highlighted.

2.7 Rescue operation

The rescue operation was conducted under the prevailing circumstances in an efficient manner without any delays that made the outcome worse. Consequently, SHK has not had any reason to scrutinise the rescue operation further.

3. Causes/Contributing factors

The accident was caused by failings in ordering, manufacturing and verification of new control arms on the trains operating on Jetline. This led to a control arm with insufficient strength being used on the train and breaking.

A contributing factor to the serious consequences of the accident was that the passenger restraint structure was not designed for the forces that arose.

Underlying factors for the accident at a systemic level were:

- the lack of a fixed and established method at the amusement park for identifying, assessing and managing risks associated with the attractions.
- Unclear rules concerning the operator's responsibility for safety.
- Insufficient public supervision.

4. Safety recommendations

Gröna Lund AB is recommended to:

- Improve its safety work relating to attractions so this, as a minimum, ensures that:
  - risks in the form of organisational and technical failings that may lead to accidents are continually identified, analysed and rectified.
  - procedures are drawn up which ensure that replacement parts comply with the requirements originally set for the attraction in question,
  - checks are tailored to the operating time of an attraction and identified risks,
  - the entirety of the safety work is frequently followed up, evaluated and, when necessary, revised (see section 2.3). *(SHK 2024:07 R1)*

The Swedish Police Authority is recommended to:

- Conduct a review of the regulations concerning amusement rides. The aim of this review should be to increase the level of safety, including by ensuring that:
  - amusement park and funfair companies' responsibility for safety is highlighted more clearly, including the fact that this responsibility encompasses all the measures required in order for the attraction to have satisfactory accident safety,
  - the need for systematic safety work is reflected,
  - specific requirements for checks and inspections are introduced in order to ensure that an amusement attraction has not been subject to alterations or interventions that may reduce the safety of the attraction,
  - the general advice concerning record-keeping is supplemented so that the record for each attraction also states what maintenance measures, alterations or interventions have been implemented on the attraction,
  - references to applicable standards are updated,
  - it is made clear that the requirements concerning operation and maintenance in applicable standards also encompass amusement attractions manufactured prior to 1 July 2006 (see section 2.4). *(SHK 2024:07 R2)*

- If the review leads to the Swedish Police Authority making the assessment that sufficient changes are not possible at the level of regulations, the Police Authority should hand over the matter of necessary legislative changes to the Swedish Government. *(SHK 2024:07 R3)*

The Swedish Government is recommended to:

- Take action to strengthen public supervision of amusement parks and funfairs. Stronger supervision should include the potential to implement continual supervisory measures and supervisory visits. These activities should also include advice and information for amusement park and funfair companies about the requirements placed on the safety of amusement attractions and how these can be complied with, for example through risk analyses and a systematic approach to safety work (see section 2.5). *(SHK 2024:07 R4)*

- When necessary, take action to ensure it is possible to bring about the changes to the regulations set out in the recommendation to the Swedish Police Authority *(SHK 2024:07 R3)*, or that equivalent changes are implemented through legislation. *(SHK 2024:07 R5)*

The International Association of Amusement Parks and Attractions (IAAPA) is recommended to:

- Disseminate SHK's final report to its members and in its safety forums in order to provide members with evidence upon which to assess whether there is a need to alter requirements for restraint devices in rollercoasters. When providing such information, the observations in the report about the need for a systematic approach to safety work and the use of replacement parts in rollercoasters should also be highlighted (see sections 2.3 and 2.6). *(SHK 2024:07 R6)*

The Swedish Accident Investigation Authority respectfully requests to receive, **no later than 16 September 2024**, information regarding actions taken in response to the safety recommendations included in this report.

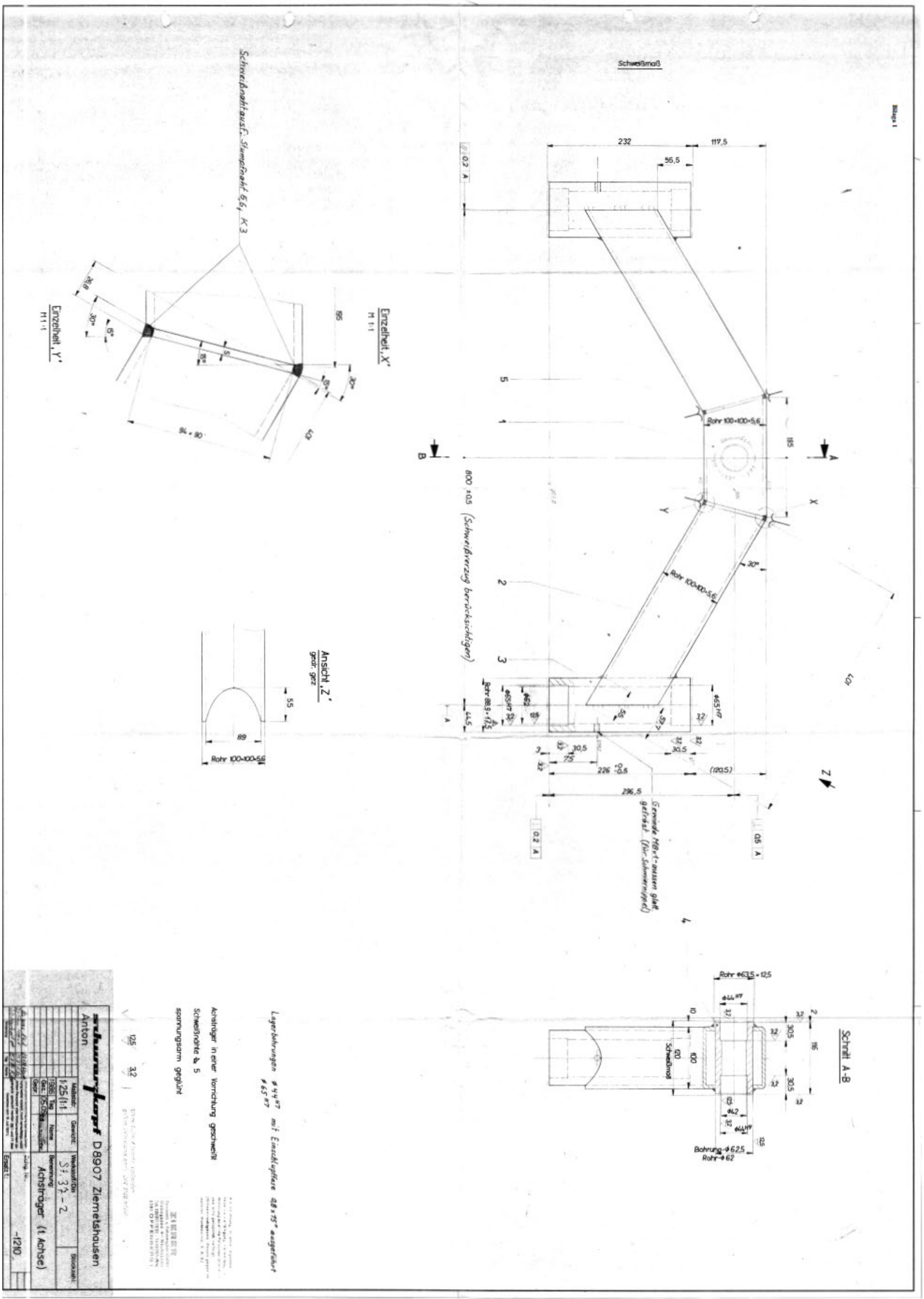
On behalf of the Swedish Accident Investigation Authority

John Ahlberk Tomas Ojala

Appendix 1 – Drawing, control arm

Appendix 2 – Actions taken, Gröna Lund

Appendix 1 – Drawing control arm



Appendix 2

Long-term development work linked to organisational safety work

Gröna Lund initiated a long-term process that aims to develop and strengthen our safety work. As part of this, we have engaged MTO Säkerhet AB, a consulting firm with a great deal of expertise when it comes to the development of organisations' safety, work environment and efficiency from a Human-Technology-Organisation perspective. This collaboration will focus on organisation, governance and the continual development of safety work within the organisation. Within the scope of the collaboration with MTO Säkerhet, Gröna Lund will ensure that all of SHK's safety recommendations are implemented.

This will include the identification, analysis and mitigation of risks in the form of organisational and technical failings that may lead to accidents. We will revise and produce procedures which ensure that replacement parts comply with the requirements originally set for the attraction in question. All inspections will be tailored to the operating time of an attraction and the risks identified, and all of the safety work will be frequently followed up, evaluated and, when necessary, revised.

Implemented changes for attraction operations

Changes and updated procedures and structures in respect of supplier orders

- New verification plan
  - Verification plan for the ordering process with a checklist and signatures for all the different stages, all the way from classification and risk assessment of the spare part to checks conducted upon delivery. The purpose of the verification plan is to serve as an aid and to track the ordering process and ensure that replacement parts comply with the requirements originally set for the attraction in question. The verification plan includes the following steps:
    - Risk assessment of replacement
    - Quality documentation
    - Proposed supplier and its qualifications
    - Tender specification
    - Technical consultation and setting of requirements with proposed supplier
    - Supplier certification
    - Request for quotation
    - Order document
    - Manufacturing inspection
    - Supporting documentation
    - Delivery checks
    - Installation checks
    - Revision inspection
    - Updating of technical dossier

- Updated ordering procedure (adheres to the verification plan above)
  - Enhanced procedure for orders of spare parts for the purpose of ensuring the quality of ordered goods and compliance with current standards.
- Updated installation checks.
  - Enhanced procedure relating to delivery checks with a traceable form.
- Updated order form for spare parts with requirements linked to the standard SSEN 13814-1:2019 being set more clearly.
- Enhanced verification procedures for suppliers
  - Inspection and continual revision of existing suppliers in order to ensure compliance with requirements under SS EN 13814-1:2019.

- Classification of spare parts on the basis of a safety perspective
  - Began in 2024 and taking place in dialogue with manufacturers and inspection bodies (one step in the combined risk assessment in accordance with SS EN13814-1:2019). The work on this type of classification has been applied to all new spare parts orders since the end of 2023.

Changes and updated procedures and structures in respect of documentation

- New documentation procedure for the attractions.
- New supervision procedure for annual revision and updating of supporting documentation for supervisory inspections. For the purpose of updating supervision and checklists for revised risk assessments for the attraction, updates, incidents and alterations to the attraction and in its surroundings.
- Updated technical dossier - clarify and quality assure digital storage of documentation linked to the attractions in accordance with that which is described in SS EN 13814:2019.
- A new digital system for servicing and checking attractions.

Information relating to previously initiated and started procedures for strategic safety work involving attractions

- Revision of risk assessment for operation and maintenance
    - Revision and review of risk assessments takes place continually for all attractions linked to operation and maintenance, taking into account age and operating time.
- Evaluation and categorisation tool for all attractions (HeatMap)
    - Visual tool for the strategic long-term work with all attractions. Parameters such as year of construction, operating time, age of control system, speed and maintenance costs are documented and taken into account. Gives an indication of an attractions lifespan and future requirement for extended and altered maintenance, as well as future investments.