Statens haverikommission
Swedish Accident Investigation Board

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Report RO 2003:01e

Accident involving a Mercedes Benz articulated bus, registration no STK 595, on Glömstavägen in Stockholm/ Huddinge, AB County, Sweden, on the 2nd of April 2002

Dnr O-003/02

SHK investigates accidents and incidents with regard to safety. The sole objective of the investigations is the prevention of similar occurrences in the future. It is not the purpose of this activity to apportion blame or liability.

Translated from the original Swedish by Dennis Lynn Anderson, at the request of The Swedish Accident Investigation Board.

In the event of discrepancies between the English and the Swedish texts, the Swedish version is to be considered to be the authoritative version.

The report is also available on our website: www.havkom.se

Statens haverikommission (SHK) Swedish Accident Investigation Board

Postadress/Postal address	*Besöksadress/Visitors*	*Telefon/Phone*	*Fax/Facsimile*	*E-mail Internet*
P.O. Box 12538	Wennerbergsgatan 10	Nat 08-441 38 20	Nat 08 441 38 21	info@havkom.se
SE-102 29 Stockholm Sweden	Stockholm	Int +46 8 441 38 20	Int +46 8 441 38 21	www.havkom.se

Statens haverikommission
Swedish Accident Investigation Board

2003-06-19 O-003/02

Swedish National Road Administration

781 87 BORLÄNGE

Report RO 2003:01e

The Swedish Accident Investigation Board (Statens haverikommission, SHK) has investigated an accident which occurred on the 2nd of April 2002 on Glömstavägen in Stockholm/Huddinge, AB County, Sweden, involving a Mercedes Benz articulated bus with registration number STK 595.

In accordance with section 14 of The Ordinance on the Investigation of Accidents (1990:717), The Board herewith submits a final report on the investigation.

The Accident Investigation Board kindly awaits a reply by the 18th of December concerning how the recommendations issued in the report have been complied with.

Göran Rosvall Henrik Elinder

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Report finalized 2003-06-19

Vehicle, registration, type	Bus, STK 595, low-floor articulated bus of type Mercedes Benz MB 0530 G Citaro
Owner/Operator	Swebus, Gesällvägen 1, 145 63 Norsborg
Date and time of the occurrence	2002-04-02, 19:15 hours in daylight *Note:* All times refer to Swedish Daylight Savings Time (UTC + 2 hours)
Place of occurrence	Local road 259, Glömstavägen near the intersection of Lovisebergsvägen in Stockholm/Huddinge, AB County, Sweden
Activity	Scheduled traffic
Weather	Light winds, good visibility, outside air temperature +2 °C
Persons on board;	
driver	1
passengers	approximately 50
Injuries to persons	1 seriously injured and 3 slightly injured
Damage to the vehicle	Limited
Other damage (environment)	Damaged pole
The driver	
Age, gender, drivers license	37 year old male, BCD license
Driver's experience on the bus type	Approximately one month
Driver's employment time	1 year and 2 months

The Swedish Accident Investigation Board (SHK) was notified on the 2nd of April 2002 that an accident involving an articulated buss had taken place on that same day at approximately 19:10 hours on Glömstavägen in Stockholm/Huddinge, AB County, Sweden.

The accident has been investigated by SHK represented by Olle Lundström, Chairman to the 15th of September 2002, Göran Rosvall, Chairman from the 16th of September 2002, and Henrik Elinder, Chief Investigator. Erik Stenbäck has assisted SHK as technical expert.

The investigation has been followed by The Swedish National Road Administration represented by Lars Carlhäll and Jan Petzäll.

Summary

On the 2nd of April 2002, (SL) Stockholm Local Traffic's regular route 746, between Skarpnäck and downtown Alby was being operated by Swebus. The bus route was being serviced with a low-floor articulated bus of type Mercedes Benz 0530 G Citaro.

After a little more than two hours of his driving duty shift, when the driver accelerated the bus on a straight section of roadway after a gentle turn and the speed was 70–80 km/hour, he noticed that the bus's rear coach began to oscillate back and forth violently. He attempted to ward off

the oscillation and at the same time to carefully apply the brakes. However the oscillations continued and after approximately 200 meters, he was unable to prevent the bus from departing the roadway off the right side and continuing down into the roadside ditch.

Finally, the bus came to rest with the forward portion transverse the roadway and the aft coach in the ditch. After about 15 minutes the police and the rescue service arrived at the site and assisted the injured and shocked persons.

The bus type is articulated with the engine placed farthest back in the rear coach. In order that this articulated bus construction shall not become unstable during certain driving conditions, standard equipment on the articulated joint is a computerized articular braking system. The investigation has shown that a technical failure occurred in this system, due to improperly performed electric cable routing.

The accident was caused by a failure within the bus's articular braking system, which caused the bus to become unstable. Contributory has been that the driver had not been sufficiently informed about the consequences of a possible failure within the bus type's articular braking system and about which steps should be taken should such a failure arise during driving.

Recommendations

The Swedish National Road Administration is recommended to:

– make every effort to insure that measures are taken in connection with type training, so that drivers of articulated buses with rear-wheel drive are informed about the bus construction's special driving characteristics and how one should react to a possible failure within the system. *(RO 2003: R1e)*,

– make every effort to insure that articular braking systems on rear-wheel driven articulated buses are made redundant. *(RO 2003: R2e)*,

– make every effort to insure that the computerized warning systems on buses become so reliable and so user-friendly that they can in practice be used with the intention of promoting traffic safety. *(RO 2003: R3e)*,

– make every effort to insure that routines are introduced about how information concerning the traffic safety status of buses shall be conveyed from the off-going driver to the oncoming driver in connection with vehicle changes. (*RO 2003: R4e)* and

– make every effort to insure that distinct rules are created within bus traffic operating companies concerning responsibility and authority with regard to traffic safety. *(RO 2003: R5e)*.

1 FACTUAL IMFORMATION

1.1 History of the sequence of events

On the 2nd of April, Stockholm Local Traffic's regular route 746, between Skarpnäck and downtown Alby was being operated by Swebus. The bus route was being serviced by a low-floor articulated bus of type Mercedes Benz 0530 G Citaro.

When the driver began his work shift at approximately 17:00 hours, he took-over the bus from the off-going driver in Hallunda. He was informed by this driver that the yellow warning light on the instrument panel illuminated at times. The bus traffic control center had however issued authorization for the bus to continue in service. The off-going driver had also observed the red light blink a few times. This however was not mentioned during the driver changeover. When the driver began his shift he noticed that the yellow light illuminated once in a while, but otherwise the bus seemed to perform quite normally.

At the first termination stop the driver attempted to get the warning light to go out by temporarily turning off the main power, as he knew by experience that failure indications could sometimes disappear by applying this measure. However the warning light continued to go on and off as previously. The driver's recollection is that the text "articular" – or something similar – appeared on the information display of the instrument panel. By using the "browse button" he was able to obtain a numerical code for the fault. He did not however understand the implications of the code.

Later during his driving shift the driver was contacted by traffic control over the radio. Control asked if the yellow warning light was still illuminated. At this time the driver informed them that the light came on at times, but he received permission to continue his driving. He has no recollection of seeing the red warning light illuminate or that he heard any auditory warning signal.

The accident occurred a bit more than two hours into the driver's shift, as he was driving along Glömstavägen in the direction of downtown Alby. Subsequent to a gentle turn he accelerated the bus on a straight section of road. When the speed was 70–80 km/hour he realized that the bus's rear coach began to oscillate violently, totally without forewarning. He attempted to ward off the oscillation but was unsuccessful. Some of the passengers in the bus became panic stricken and screamed.

Simultaneously as the driver attempted to ward off the oscillation he began to brake carefully. However the oscillation continued and after approximately 200 meters, he was unable to prevent the bus from departing the roadway off the right side and continuing down into the roadside ditch. Finally, the bus came to rest with the forward portion transverse the roadway and the aft coach in the ditch.

The passengers, some of whom were injured, were forced to evacuate the bus through the rear doors because the forward door could not be opened. In connection with the evacuation a certain amount of tumult arose among the passengers and one of them threatened the driver's life. The driver contacted traffic control and notified them about what had happened and that some of the passengers had been injured. He experienced the situation as very traumatic and was shock-stricken.

After about 15 minutes the police and the rescue services arrived at the site and assisted the injured and shocked persons.

1.2 Injuries to persons

	Driver	*Passengers*	*Other*	*Total*
Fatal	–	–	–	–
Seriously injured	–	1	–	1
Slightly injured	1	2	–	3
No injuries	–	approx. 47	–	approx. 47
Total	1	approx. 50	–	approx. 50

1.3 Damage to the bus

Limited.

1.4 Other damage

A street light pole was damaged.

1.5 The rescue effort

The driver alerted the rescue services via the Swebus traffic control. The first ambulance arrived on the scene about 15 minutes after receipt of the alarm. The injured – one seriously and two slightly – and in addition the shock stricken bus driver were transported to the hospital. The other passengers were able to depart the scene with a regular bus that arrived after the accident bus.

1.6 The driver

The driver, a male, was 37 years old at the time and held a driver's license of Class BCD. The driver was employed with the company on the 5th of February 2001.

1.7 The bus

1.7.1 General

Manufacturer:	Mercedes Benz
Type:	MB 0530 G Citaro, low-floor articulated bus
Serial number:	5467
Year of manufacture:	2002
Registration	STK 595
Total mileage:	8,900 kilometers

The bus type has three wheel axles and is articulated. It is built for densely trafficked areas with door positions 2+2+1+0 and has room for 49 sitting and 67 standing passengers (BK 1 road). It is equipped with a speed governor, which limits the speed to a maximum of 100 kilometers per hour.

The bus was delivered to Swebus on the 3rd of March 2002. At the time of the accident the bus had a total mileage of approximately 8,900 kilometers.

The bus had a valid traffic certificate.

Mercedes Benz MB 0530 G Citaro

1.7.2 *Power train and control systems*

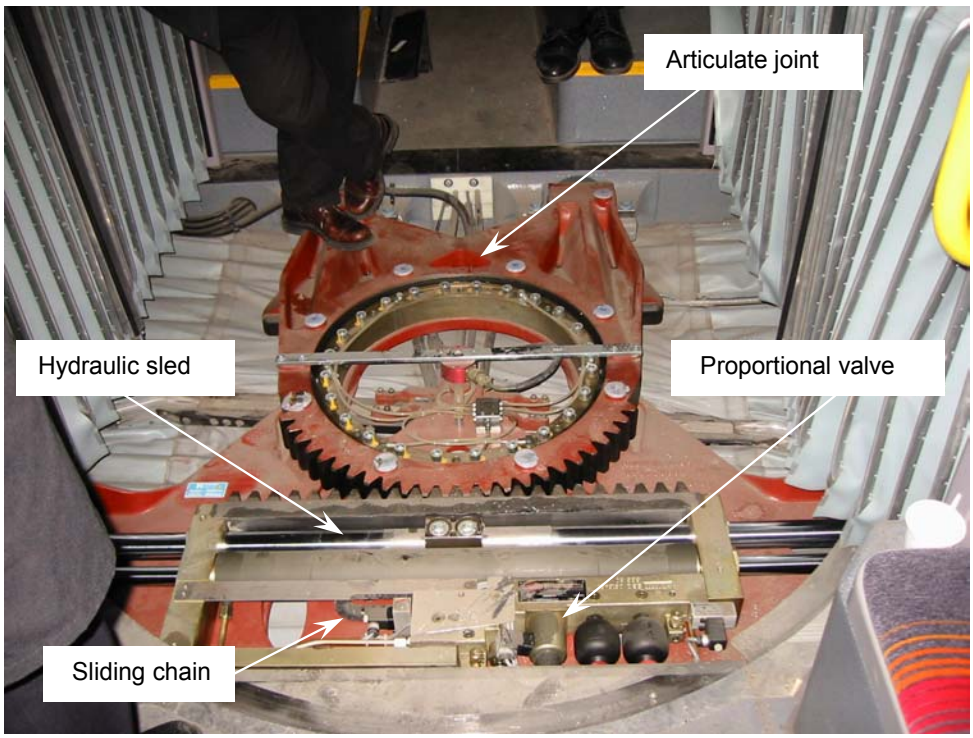
The engine is placed farthest back in the rear coach and power transmission takes place through the rearmost set of wheels (so-called pushertype). In order that this articulated bus construction shall not become unstable during certain driving conditions, as standard equipment the bus joint is fitted with an active computerized dampening system, in the case at hand of type Hûbnerled HNGK 9.2W.

The system automatically regulates the dampening (resistance) in the movements of the articular joint, taking into consideration, among other things, steering and joint angles, speed, acceleration and retardation. On the type of bus here under investigation, Mercedes has developed the software for the dampening system, which has been integrated with the other computerized electrical and control systems of the bus.

The mechanical dampening of the articular joint takes place hydraulically through the movement of hydraulic fluid between two chambers within a hydraulic cylinder when the joint is in motion. Dampening occurs through the process of restricting the flow of hydraulic fluid between the chambers. This restriction of the flow is accomplished with the help of a so-called proportional valve that has the task of regulating the flow of hydraulic fluid and accordingly the resistance to movement.

The proportional valve is mounted, together with the other dampening hydraulics, on a moveable so-called hydraulic sled on the articular joint. The valve is electrically regulated and supplied with electricity via a moveable cable between the joint's stationary and moveable parts. As the voltage fed to the valve is increased, the hydraulic fluid flow is reduced and the dampening of the joint increases.

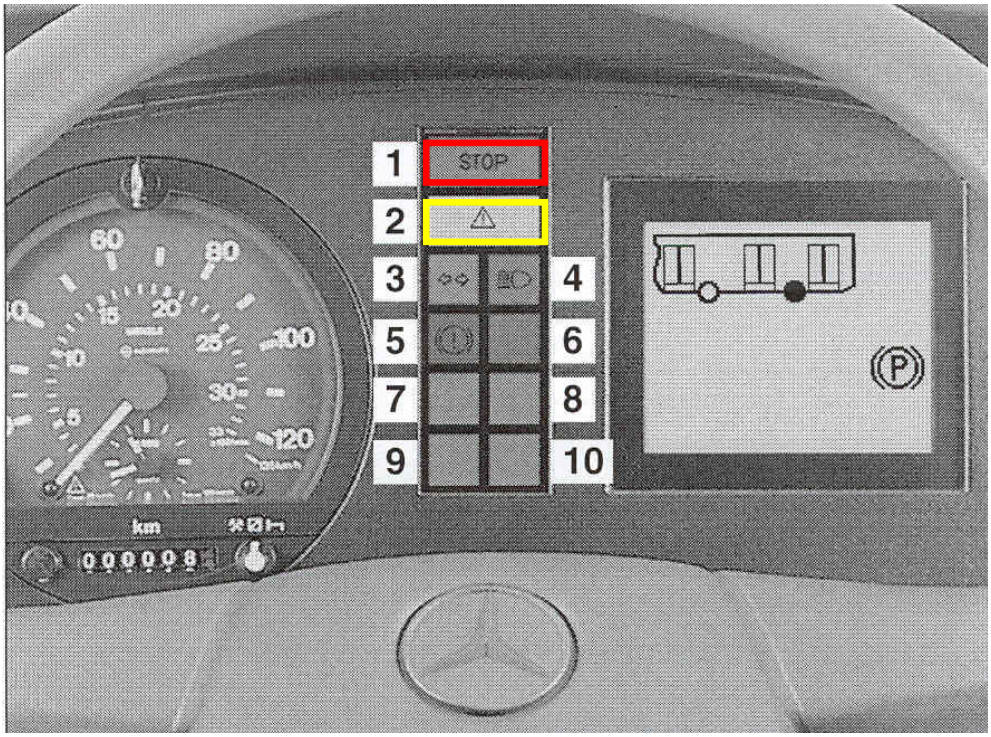
In order to prevent the cable from being damaged, it is mounted in a so-called sliding chain, made of plastic. The system is not doubled, which means that the articular joint becomes completely non-dampened if the electricity to the valve is cut-off.



The bus's articulate joint section with removed floor plates

1.7.3 *Warning system*

The Citaro bus type has a computerized control and warning system that assists the driver in monitoring the technical status of the bus and produces a warning if any failure should arise that might affect the road safety of the bus. Included in this system, among other things, are an information display with both text and images that is positioned on the right-hand portion of the instrument panel and two warning lights, one red and one yellow, placed directly in front of the driver. The red warning light illuminates if a serious failure affecting road safety occurs and signifies that the bus is not to be driven any further. When the red warning light is illuminated for more than two seconds an auditory warning signal is also activated. The yellow light is illuminated if a failure occurs which does not directly affect the road safety of the bus. Several different types of failure indications can be stored in the data memory for subsequent analysis and troubleshooting.



Instrument panel with warning display

1.8 Meteorological information

At the accident site, at the time of the accident, the wind was light, the visibility good and the air temperature +2 °C. The road surface was dry. Official sunset was at time 19:32 and the driver has stated that the sun had not blinded him.

1.9 Regulations relevant to the accident

The Citaro bus type has been approved through an established registration inspection and is certified for public transportation.

According to what SHK has learned, there are no general regulations concerning how articular joints in articulated buses shall be constructed and controlled. Instead, during the certification of new types of buses, the steering characteristics and driving stability are verified by means of several types of driving tests.

There are no longer any general norms concerning how bus warning systems shall be designed and presented to the driver. A standard system existed earlier, called Normbus 90, including among other things, instructions about the function and placement of main warning lights. During the deregulation that was carried-out during the 90s, the work of renewing this standard was ceased, and all bus manufacturers do not use it any longer.

Within The Swedish National Road Administration, a continuous process of implementation of the European Union's bus directives into the Swedish vehicle regulations is taking place.

1.10 Maintenance

The bus was maintained in accordance with valid regulations.

Concerning the articular joint of the bus, there are no requirements for either periodical inspections or in-service time limitations for the cable harness supplying the system's proportional valve.

1.11 Road specifications

In the vicinity of the accident site the road has an approximately 350 meter long straight section without hills. The forward visibility is good. On the left-hand side of the road, in the direction of travel of the bus, there is farmland and on the right-hand side there is a residential district.

The surface of the road is asphalt, two-lane and about 10 meters wide. At the time of the accident, the roadway surface was repaired in several places. During the Road Administration's latest survey of the road prior to the accident, an unevenness factor of approximately 2 millimeters/meter and a rut depth of approximately 10 millimeters were measured.

The road is used by approximately 12,000 vehicles per day. The speed limit is 70 km/h.

1.12 Trip recorder

The bus was equipped with a trip recorder. At the time of the accident there was no recording card installed in the recorder. There is no requirement for a trip recorder for buses in public transport.

1.13 Accident site and bus

1.13.1 The accident site

The accident occurred on Glömstavägen approximately 100 meters prior to the intersection with Lovisebergsvägen. The bus ran down into an approximately one-half meter deep ditch on the right-hand side of the roadway.

The accident site viewed opposite the direction of travel of the bus

1.13.2 The bus

As a consequence of departing the roadway the bus sustained damage to a bellows, a suspension link and air and water pipes. There was also sheet metal and glass damage on the right-rear section of the bus. Initially the bus was towed to the Swebus depot in Botkyrka. After temporary repairs of the compressed air leakage, the bus was driven to Evobus in the Lunda industrial area for further technical investigation.

1.14 Medical information

Nothing has been found that would indicate that the physical or mental condition of the driver was impaired during his driving shift.

1.15 Fire

There was no fire.

1.16 Survival aspects

Thanks to the fact that the bus did not overturn and that the retardation forces were relatively low, injuries to persons were limited; this, despite the fact that none of the approximately 50 people on board used a seatbelt. (Seatbelts were not installed and they were not required).

1.17 Tests and research

1.17.1 General

After the occurrence the bus was transported to Evobus in Lunda for technical investigation. The investigation has been accomplished under the supervision and control of SHK and in consultation with representatives from SL, Swebus, Mercedes and Hûbner.

1.17.2 Registered fault indications

Five indications of faults had been stored in the bus's on board computer. One of these indications referred to an electrical power interruption to the proportional valve of the articular joint's dampening system. A failure such as this should normally cause the red warning light to be illuminated.

Four indications referred to other disturbances in the dampening system of the articular joint. These were of a less serious character and would normally lead to the yellow warning light being illuminated.

Neither have any of the above named types of failures been found, nor has it been possible to re-create them subsequent to the accident. It cannot however be ruled out that these disturbances arose in connection with the abnormal stresses that the bus's different systems were exposed to during the accident itself. The indications may also have referred to transitory faults that did not reappear.

1.17.3 Technical investigation

During the technical investigation of the bus it was found that an electrical cable breakage had taken place within the electrical cable of the articular

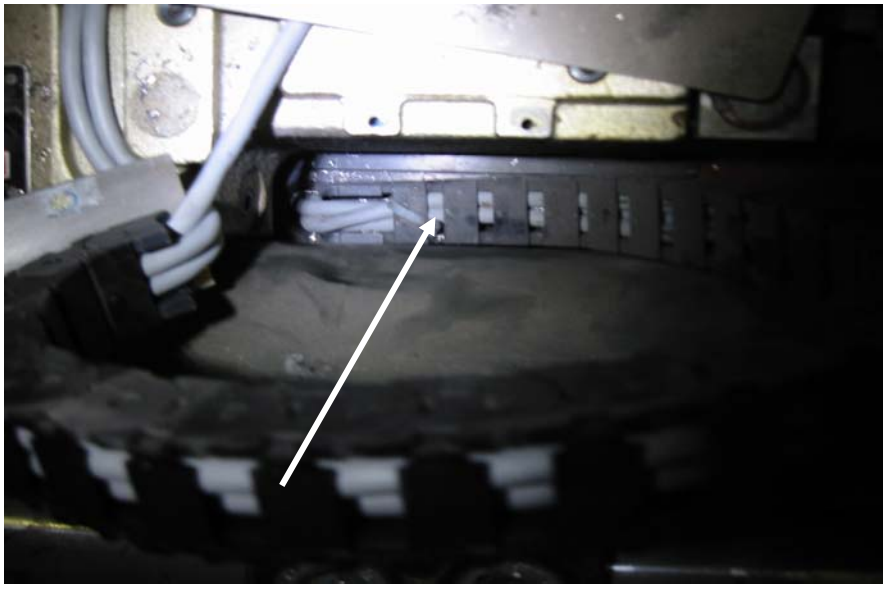
joint dampening system that supplies the proportional valve with electricity. Depending upon how the cable was bent back and forth, the electrical power was connected and disconnected respectively within the electrical contact at the location of the breakage.

As a part of the troubleshooting, the cable was reinstalled in its original position and the bus was thereafter test-driven. During this test drive the red warning light came on and went off repeatedly in connection with negotiating curves on the road. When the warning light was illuminated the auditory buzzer sounded and the text “Interruption Articular Control” was shown on the display. The faults were also registered in the on board computer. The yellow warning light was never illuminated during the test drive.

Nothing was discovered in the investigation that would indicate that there was any failure in the bus’s warning system.

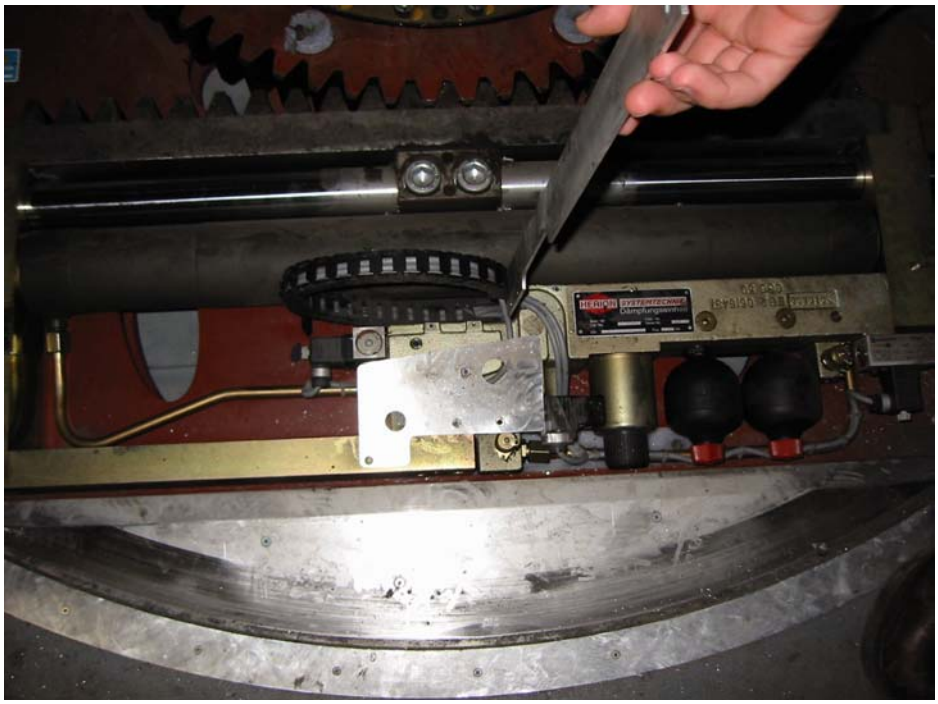
During the investigation of the cable mounting within the cable sled, the following deviations from the cable manufacturer’s installation directions were found.

- The securing of the cable to the ends of the sliding chain was improperly carried-out. The so-called cable-tie, which is used to secure the cable, was mounted around several cables. In a correct installation, each cable-tie shall be installed around only a single cable.



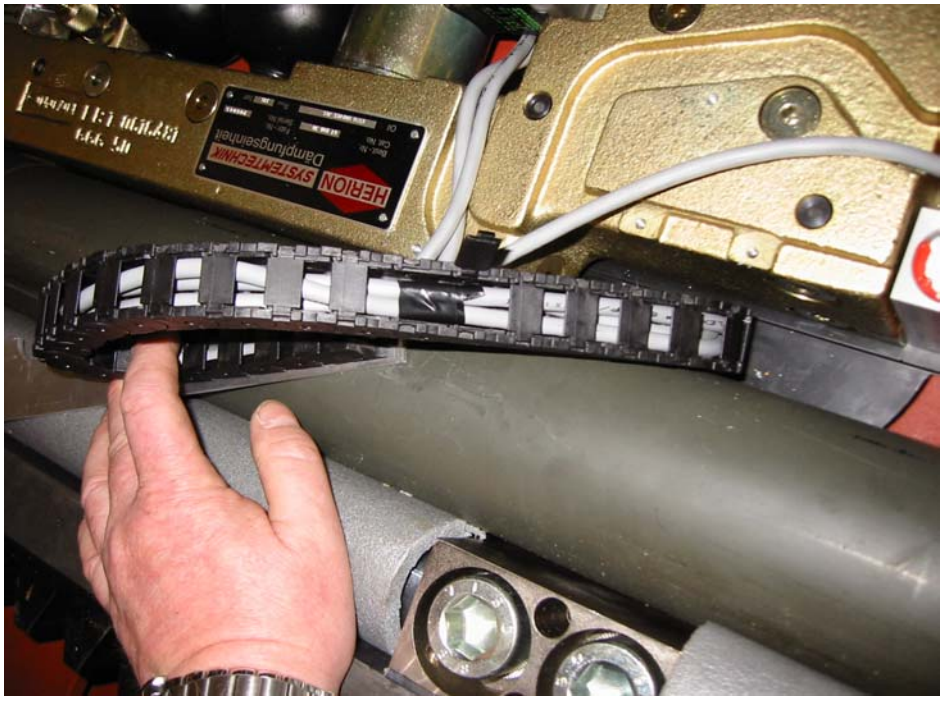
Several cables secured with the same cable-tie

- The cables were drawn tightly through the sliding chain. When correctly installed the cables should be able to move freely without any tension force applied. The cables are not to be secured to each other within the sliding chain.



A strained cable

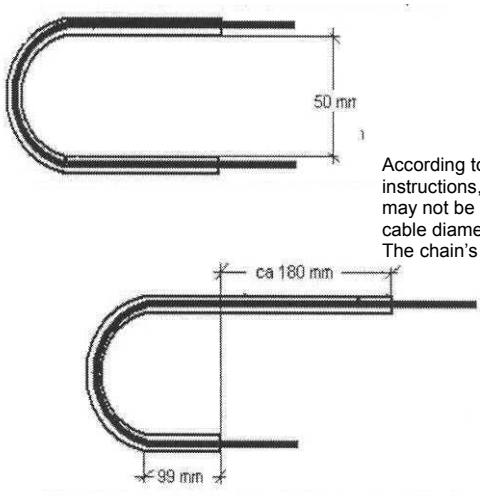
- The width of the sliding chain was insufficient in order that the three cables could lie free next to each other. The cables were lying on top of each other and in several places they were crossed.



Crossing cables

- The curve radius and the length of the sliding chain did not meet the manufacturer´s specifications.

The insulation of the cable installed in the sliding chain is LAPP Ölflex 8555P 2x1mm2. The cable diameter is 6.6mm



According to the manufacturer's instructions, the cable curve radius may not be less than five times the cable diameter, i.e. 5x6.6mm=33mm. The chain's curve radius=25mm

According to the manufacturer, the portion of the cable that is not exposed to bending shall be 15 times the cable diameter, i.e. 15x6.6mm=99mm. The allowable lateral movement would then be approximately 180mm. In practice, the lateral movement is approximately 300mm.

Extract from the manufacturer's specifications

1.17.4 Material analysis of electrical cable

The electric cable was removed from the bus and sent to The Swedish Testing and Research Institute (SP) for investigation.

The investigation showed that a fracture had taken place in the internal copper wiring of the cable, probably due to the cable being subjected to higher tension and bending forces than it was dimensioned for.

The cable insulation was intact and there were no signs of manufacturing defects or handling damage. The break in the wire had occurred at about the center of the sliding chain that guides the cable in the transition between the stationary portion of the articular joint and the moveable sled. The fracture surfaces on the copper wire were typical for fatigue fractures.

1.18 The company

1.18.1 Swebus

Swebus is a nation-wide company that conducts several forms of bus traffic domestically and abroad. The company has approximately 9,000 employees and operates with approximately 3,500 buses of different types. The company is sub-divided regionally and operationally with a large number of depots. The Botkyrka depot, which operated the bus here under investigation, has approximately 120 buses.

1.18.2 Bus traffic control

During traffic operations that are performed on behalf of SL, the drivers are radio-directed by Swebus' own traffic control center.

On the morning of the 2nd of April 2002 the on-duty traffic controller was contacted by the driver of the actual bus, who reported that the yellow light was illuminated and the text "Articular System" was shown on the warning display. After having contacted the Swebus maintenance shop, the traffic controller informed the driver that he could continue to operate the bus. The traffic controller wrote a so-called failure report concerning the occurrence. It has not been possible to locate this failure report, but the traffic controller who was on duty at the time of the accident had been informed that the yellow warning light in the bus was illuminated periodically. As his understanding of the situation was that none of the drivers had observed anything else other than a blinking of the yellow warning light, and with the thought in mind that warning lamps could sometimes be illuminated in the absence of any failure, he judged that the bus could continue in service. He had planned to exchange the bus the next time it transited Alby.

1.18.3 Fault indications

According to Swebus's production chief in Botkyrka, it is not uncommon for warning lights in buses to illuminate without subsequently being able to locate any fault. He is of the opinion that it would be difficult to successfully operate traffic if one was to pay attention to all "false alarms".

Sometimes buses are operated with warning lights illuminated until the next scheduled maintenance shop visit. This is not however applicable if the red warning light is continuously illuminated. In this case it is not allowed to drive the bus until it can be determined with certainty what the cause of the warning was. If such a fault cannot be remedied on-site the bus is removed from traffic operations. Subsequently the maintenance depot determines if the bus is to be towed or if it is possible to drive it to the maintenance shop.

1.18.4 Type training on the bus

During the introduction of this bus type the drivers concerned completed a theoretical course approximately two hours in length. Included in the course was a summary of the bus warning system, including the functions of the red and yellow warning lights. It was pointed-out that the bus was not to be driven if the red light was illuminated.

The course did not treat the complex of problems concerning articulated buses that have rear-wheel drive or the necessity that such buses have a functioning dampening system for the articular joint. There were no guiding principles presented concerning how a driver should react if a sudden failure should arise in the system.

The manufacturer's driver handbook has been judged to be too complicated to issue directly to drivers. Swebus has therefore developed their own information leaflet in the form of a two page A4 format with pictures of the instrument panel and an explanation of the functions of buttons, lights and instruments. It is not evident from this information leaflet what the implications of the possible warning texts on the information display entail. There is no demand on the part of the company that drivers who operate the bus must have completed this type training. However, according to company practice, drivers who have not received training on a certain type of bus, always have the right to choose another bus type.

1.18.5 The conditions of responsibility

Formally it is the responsibility of each driver to verify that the bus that they take-over and begin to operate complies with valid traffic safety requirements. In practice it is generally considered that it is traffic control that monitors the condition of the buses that are in operation.

A work shift for a driver can entail five or six changes between different types of buses and different routes. Most changeovers take place out on the bus routes unless the bus is to be taken out of traffic or driven back to the garage. For driver replacement out on the routes, the drivers use a regularly scheduled bus route, however there are a number of driver-relief cars that are used for this purpose as well.

Should any problem of a technical nature occur that implies that the driver questions whether the bus should continue in service, he is supposed to consult with traffic control as to how the situation should be handled.

1.19 Other information

1.19.1 Similar previous incidents

In August of 1999 a similar incident occurred involving an articulated bus equipped with a joint dampener of type Hûbner HNGK 6.2 W. As the result of electrical power supply loss to the proportional valve during highway driving, the aft coach began to pitch back and forth violently. The driver did not succeed in maintaining the bus on the roadway and it ran off the highway.

1.19.2 Measures taken

Among other things, as a consequence of the accident here under investigation, the following measures have been taken:

- Regarding buses equipped with this type of articular joint, The Swedish National Road Administration has recommended manufacturers and general agents in Sweden to introduce a speed limit of 50 km/h until the problem is rectified.
- SL has introduced a maximum speed limit of 50 km/h for this bus type within their traffic system until the problem is rectified.
- Swebus has informed their drivers how they should counteract possible rear coach occilations on an articulated bus. Furthermore, it is now forbidden for drivers to continue operating a bus in which the yellow warning light is illuminated until the cause of the fault has been definately determined.
- On the initiative of The Swedish National Road Administration, the problem with the dampening system has been discussed with applicable vehicle manufacturers and general agents at a meeting on the 5th of June 2003. During this meeting a program was prepared for the replacement of the electrical cables with cables that are manufactured according to current specifications. The Road Administration also assigned the vehicle manufacturers the project of inquiry into whether the construction of the Hübner joint can be considered to be sufficiently safe or if reconstruction with possible redundancy of certain components is necessary. The results of this investigation are to be presented to the Road Administration during 2003.

2 ANALYSIS

2.1 The accident

From a viewpoint of traffic safety this was a very serious accident. The driver suddenly lost control of the bus, which was cast across both lanes of the roadway. In this case, it was fortunate that there was no oncoming traffic and that the deceleration of the bus in the ditch was relatively gentle.

The technical investigation of the bus has shown that the dampening system for the articular joint between the bus's forward and rear coaches ceased to function. Due to the fact that the rear-most pair of wheels propels the bus, the result was that the bus suddenly became unstable and very difficult to maneuver.

The driver had certainly seen the yellow warning light go on and off while driving the bus and was aware that there was possibly some fault in the bus; however when the bus suddenly became almost completely uncontrollable, this came as a total surprise to him. He had not received any information about the risk of this phenomenon nor how one should react in such situations in order to regain control of the bus. Therefore he was not successful in preventing the bus from finally running off the road.

Considering the bus type's unexpected behavior when the articular joint's dampening system ceases to function, drivers who operate the bus should be informed during type training about the bus construction's special driving characteristics and how, as a driver, one should react during a possible failure of the dampening system.

2.2 Failure analysis

The technical investigation has shown that the electrical cable to the proportional valve was incorrectly installed in the sliding chain that is supposed to relieve tension on the cable. This incorrect installation caused bending and tension loads on the wire that it was not designed for and it therefore broke as a result of metal fatigue after only a short time in operation. When the bus was driven straight ahead, the elasticity of the cable insulation allowed the internal wire to have contact at the point of breakage. When the bus turned, tension arose in the wire, which caused the electrical contact to be broken temporarily. This may explain why the failure appeared intermittently.

In the gentle curve that the bus negotiated prior to the accident site, it is probable that such an electrical current failure occurred, which resulted in the complete opening of the proportional valve, which essentially removed all dampening.

2.3 The articular braking system

The low-floor articulated bus has many operational advantages concerning passenger transport in heavy city traffic. The floor surface is low and there are no stairs in the center aisle. It is easy for passengers to board and exit the bus. The disadvantage is that the driving force from the rearmost wheels of the rear coach implies instability in the direction of travel and makes the bus tend to "jackknife" in connection with acceleration in curves. The articular braking system can be considered a "temporary solution" to

overcome this problem. As the functioning of the system is decisive to the stability of the bus and traffic safety, it is surprising that there is no system redundancy if a failure should arise.

Even if the driver does receive a warning signal if a failure should appear in the system, this is of little help if the failure appears during driving at highway speed and the bus suddenly becomes uncontrollable. The system should therefore be doubled or fitted with a separate safety system that eliminates the risk that uncontrollable oscillations can arise during driving operations.

2.4 The warning system

The bus type has an advanced and computerized warning system that is to facilitate the driver's control of the vital systems of the bus and to contribute to traffic safety. But if the warning system is so complicated that neither drivers nor traffic controllers understand it, the effect can be the opposite.

The final breakage of the electrical cable probably took place at some point during the day of the accident and gave rise to the "blinking" red light that one of the drivers noticed. It cannot be ruled-out that a loose contact had existed during other occasions as well, but that this was not noticed by the drivers or was mistaken for a yellow warning if the interruption was less than two seconds and therefore did not activate the auditory warning.

Contributory to the fact that the driver did not observe and react to a possible red warning light may also have been that erroneously blinking warning lights, both red and yellow, are something that drivers have become used to and forced to accept. Many times they have also been successful in rectifying the problem simply by restarting the bus's computer system.

2.5 Traffic safety responsibility

Many driver duty shifts are complicated, with several planned bus changes out in traffic. At times this makes it difficult for the drivers to accomplish the required safety inspection of each new bus that they take-over. To a large extent, the drivers are forced to depend upon the bus having been safety checked when it is put into traffic for the day and that each off-going driver actually reports all failures that may have occurred. SHK has not found any systematic routine for the reporting of the bus's condition from the off going to the oncoming driver. Even if such a system had possibly not prevented the accident, there is however reason to develop and introduce such a system.

Regarding more complicated technical disturbances, the drivers are forced to a great degree to depend on the instructions and decisions of traffic control concerning whether the bus may continue in service or not. Respectively, the traffic controller must many times rely on verbal information from "the maintenance depot". The division and regulation of responsibility and authority with respect to traffic safety within the company and the company's routines to guarantee that the traffic program is carried-out with buses that are always in a traffic-safe condition seems therefore not to be completely clear.

3 CONCLUSIONS

3.1 Findings

a) The driver was qualified to drive the bus.
b) The bus had a valid traffic certificate.
c) The bus type requires a functioning articular joint braking system in order not to become unstable.
d) A technical fault arose within the articular joint braking system.
e) Electrical cable installation in the articular joint braking system was incorrectly performed.
f) The driver's knowledge about the bus type's special stability characteristics and its warning system was limited.
g) As a consequence of the accident, The Swedish National Road Administration, the operators and the manufacturers have taken several traffic safety enhancement measures.

3.2 Causes of the accident

The accident was caused by a failure within the bus's articular braking system, which caused the bus to become unstable. Contributory has been that the driver had not been sufficiently informed about the consequences of a possible failure within the bus type's articular braking system and about which steps should be taken should such a failure arise during driving.

4 RCOMMENDATIONS

The Swedish National Road Administration is recommended to:

– make every effort to insure that measures are taken in connection with type training, so that drivers of articulated buses with rear-wheel drive are informed about the bus construction's special driving characteristics and how one should react to a possible failure within the system. *(RO 2003: R1e)*,

– make every effort to insure that articular braking systems on rear-wheel driven articulated buses are made redundant. *(RO 2003: R2e)*,

– make every effort to insure that the computerized warning systems on buses become so reliable and so user-friendly that they can in practice be used with the intention of promoting traffic safety. *(RO 2003: R3e)*,

– make every effort to insure that routines are introduced about how information concerning the traffic safety status of buses shall be conveyed from the off-going driver to the oncoming driver in connection with vehicle changes. (*RO 2003: R4e)* and

– make every effort to insure that distinct rules are created within bus traffic operating companies concerning responsibility and authority with regard to traffic safety. *(RO 2003: R5e)*.