Incident report

D 1/2001 Y,
Shortened Version

Bus Fires in Finland during 2001

Translation from the shortened Finnish Version

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Accident Investigation Board Finland

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ISBN 951-836-090-1

Multiprint Oy, Helsinki 2002

PREFACE

In the autumn of 2000 the Accident Investigation Board of Finland started the Bus Fire Project led by accident investigator Esko Lähteenmäki with Esko Värttiö, chief accident investigator, and accident investigator Reijo Mynttinen, all from the Accident Investigation Board as members of the team. Statistics of, and reasons for fires in buses were determined as project objectives. In the investigation report a summary of the fires, the causes of them, and passenger safety issues had to be presented, and safety recommendations made.

The regional emergency services were asked to inform the person on duty at the Accident Investigation Board of any bus fires immediately. In addition insurance inspectors were asked to inform investigators of fire incidents.

A 'Bus Fire Investigation' form was sent in connection with the incidents to the bus driver involved and bus company owners for completion. From the form information about the vehicle and the fire incident, needed for the statistics, was obtained.

During 2001 a total of 38 fires in buses came to the investigators' attention. It is reasonable to assume that there were even more cases involving minor damage during the research period but they have not have come to the investigators' attention.

The Incident Report for fires in 2000 (D 1/2000 Y) was published by the investigation board in the spring of 2001. The Incident Report was sent to all bus company owners with 10 or more vehicles. Furthermore, the Incident Report can be read on the home pages of the Accident Investigation Board of Finland. Interest in the publication has been shown by bus owners, bus organisations and the press.

During the project the investigators had participated in some training sessions in the area of coach services and had become familiar with the activity of the bus company owners' repair workshop. These presented opportunities for informing about the purpose and operation of the project. At the same time the investigators obtained valuable information from technical experts in the field of coach services. The project has also been written about in vehicle magazines.

It was decided to continue the Bus Fire Project during the year 2001. This way a comparison with the fires of the year 2000 was obtained. The Bus Fire Project for the year 2000 started only at the beginning of September so the information about fire incidents prior to this month is incomplete and there may be incidents which had not been reported to the investigators. In 2000 33 incidents were studied and 38 incidents in 2001. From these numbers one can conclude that the number of the cases has diminished as prior to the beginning of the project the annual number of fires reported by the insurance companies was about 50. However, a follow-up period that lasts for two years is too short to reach conclusions about whether the recommendations made have improved the situation or whether the reduction in fires is due to normal statistical variation.

This investigation report has been submitted for review to the Ministry of Transport and Communications, the rescue department in the Ministry of the Interior, the Finnish Vehicle Administration,

and the Finnish Motor Insurers' Centre. In addition, a draft was sent for unofficial statement to bus company owners and to other interest groups (10 in total).

The project group thanks those individuals, bus company owners and other interest groups who contributed to fire incident information during 2001. The project group has come to the conclusion that during these last two years cooperation with the bus owners has worked well, and the attitude towards the fire safety has improved and a responsible operation has developed. Many flaws that have been observed in the investigation have been corrected but yet the same type-specific causes as in the year 2000 have been repeated.

In this shortened investigation report Section *1 Incidents and investigations by incident* have been expressed in table format. Furthermore, the section containing *Statements* has been omitted.

SUMMARY

During 2001 38 fires were brought to the investigator's attention, ranging from a small fire to the total destruction of the vehicle. The criterion for a fire was an open flame and that an effort was actively made to extinguish it.

Of fires investigated 30 (31)[1] started from outside the passenger compartment. Of these 16 (21) started in the engine compartment, nine (7) in the brakes and four (3) from under the body. Four (5) of the fires which started outside the passenger compartment progressed into the cabin. In all four (2) of these incidents the vehicle was irreparably destroyed. Eight (2) fires started within the passenger compartment. In the fires which had started within the passenger compartment one (1) of the vehicles was destroyed.

In 17 (9) vehicles there were no passengers, in five (3) there were fewer than 10 passengers and in three (7) there were 30 or more passengers. There were on average 20 passengers (23). There were no difficulties in any incident in the passengers' evacuation. The doors opened as normal or backup system was used and all the passengers left independently.

Of the fires recorded 52% (76%) took place in a Volvo, others being: 37% (12%) Scania, 3% (9%) Mercedes, and 8% (3%) taking place in other models. The greatest reason for the large share of the Volvo models is the fact that Volvo represents 44% of all registered buses and 68% of all (low entry) buses in city traffic in Finland.

Reasons for fire fell into roughly five categories: fires caused by the brakes, a short circuit in the cable of a battery or generator, other electrical faults, fuel leaks and other reasons. With respect to fires in the year 2000 what was new was that there were three other fires which had started in additional heaters. The absence of additional heater fires from the statistics for the year 2000 is probably due to the fact that the statistics began only in August. The fires in 2001 which had started in the additional heaters took place in January and February.

Of the nine (7) fires caused by the overheating of brakes six (6) started from overheating in the disc brakes and three (1) from overheating of the drum brake. There were six (8) cases in which fires had started from the short circuit of the battery or generator cable. Of the 8 other incidents classified as being 'other electrical faults' 3 started in the main electrical system. Fuel leaks from the fuel system caused five (9) incidents. Of other fires three were caused by additional heaters in January and February. The reason for the fires was a fuel leak in the fuel pipes of the additional heater. Three fires were caused by air-conditioning and heater fans and one (2) fire was due to an oil leak. In one incident the fire was caused by a breakdown of the injection pump switch which caused a delay in the injection. In one case the fire was caused by the breaking of the flexible part of the exhaust pipe between the turbo and the silencer. One fire started from the air conditioner on the roof of the car.

The driver operated the fire-extinguisher in 32 (23) incidents. The first-hand extinguishing succeeded in 22 (17) cases. The most common reason for the failure was early exhaustion of the fire-extinguisher contents.

[1] The number in parantheses refers to the corresponding statistic for the year 2000.

Fire fighters were called in 29 (21) cases. The average time of arrival was 12 (11) minutes, the longest individual time was about 24 (50) minutes. In the Helsinki metropolitan area the average time was about eight (6) minutes. In 15 (10) cases only the securing and cooling of the extinguished fire remained the task of the fire fighters.

Since the completion of the previous Incident Report not enough improvements have taken place yet, The Accident Investigation Board reiterates the safety recommendations that were presented in the previous Incident Report.

Fire Prevention measures:

- The vehicle user should take care of: maintaining cleanliness of the engine and engine compartment, inspecting the condition of the fuel pipes and replacing them with new types of pipes if necessary and checking the fitting and condition of the battery and generator cables.
- The bus company owners should add to their own scheduled maintenance service program the fire safety guide "Bus and Trucks, Fire Safety Guide, 1999" drawn up by the Federation of Finnish Insurance Companies (Vakuutusyhtiöiden keskusliitto) and Insurance Group's Vehicle Repair Commission (Vakuutusyhtiöiden autokorjaustoimikunta).
- Sound and heat insulation components in the engine compartment, or their surface materials, should be fire resistant.
- Importers should compile statistics on fires in bus models that they represent. They should draw conclusions from them and should prepare a work update guide for prevention of similar fires.
- The bus owners should give drivers standard training in the use of fire warning systems of vehicles and the function of the indicators which are related to it.
- In driver training the importance of observing the driving properties of the vehicle should be emphasised.
- The drivers should always become familiar with with the instruction book of the vehicle when the vehicle type is not familiar to the driver.

Minimising fire damage:

- All new buses should be equipped with an automatic or semi-automatic fixed fire-extinction system.
- The hand extinguisher with 2 kg capacity should become at least 6 kg.
- Bus manufacturers should equip the engine compartment covers with holes for fire extinguisher nozzles, with a spring loaded lid that opens inwards. The location of the holes should be determined according to chassis and body so that the extinguisher contents may be freely directed to higher fire risk objects.
- The bus owners should give every driver fire-extinction and evacuation training and at regular intervals should arrange training in the use of fire-extinguishers.

The Accident Board presents, as new recommendations:

- The additional heaters of vehicles and their fuel pipes should be checked before the beginning of the heating season.
- The compression joints should be used in the injection lines only as a temporary measure to transfer the vehicle to the repair workshop, not as a permanent solution.

CONTENTS

1 INCIDENTS AND INVESTIGATIONS BY INCIDENT

In this part the fire incidents are presented in chronological order in table format. The project group was informed of 38 bus fires varying from a small fire to the total destruction of the vehicle. The criterion for a fire was an open flame and that an effort was actively made to extinguish it. Incidents only involving overheating and smoke have not been included. Statistics on the fires are reported later with respect to different variables. Safety recommendations are presented in section 5.

Incident No	Date	Vehicle		Year of model	Traffic form	Fire	
		Chassis	Body			Severity[2]	Cause
1.1	13.1	Scania 112	Kutter	1985	City	2	Overheating of the drum brake
1.2	13.1.	Scania L113	Lahti 402	1996	City	1	Fuel leak in joint of fuel pipe in additional heater
1.3	17.1.	Scania L113	Lahti 402	1997	City	1	Short circuit between cable connector and the cover of the starter motor
1.4	26.1.	VW City bus	Kuzeniz	1995	Long distance	1	Ignition of the wiring loom behind the dashboard due to overloading
1.5	2.2.	Volvo B10B LE	Carrus	1998	City	1	Overheating of the disk brake
1.6	3.2.	Volvo B10B LE	Carrus K-204	1997	City	1	Fuel leak in joint of fuel pipe in additional heater
1.7	5.2.	Scania K112	Trafora Finnliner 370	1988	Long distance	1	Fuel leak in fuel pump in additional heater
1.8	10.2.	(Venäläinen)		1988	Charter	2	Short circuit in air conditioner
1.9	11.3.	Volvo B9M	Wiima KK2	1987	City	2	Short circuit caused by the wearing away of the generator cable insulation
1.10	23.3.	Volvo B10B LE	Ikarus	1999	City	1	Overheating of the disk brake
1.11	31.3.	Scania	Delta Super Star	1992	Charter	1	Short circuit in the electrical centre
1.12	8.4.	Scania K112	Ajokki Royal	1988	Charter	4	Overheating of fluorescent lamp choke coil / inverter
1.13	9.4.	Volvo B10L	Carrus City U 204	1998	City	1	Oil leak caused by broken turbo shaft
1.14	11.4.	Volvo B10M	Carrus Delta 602	1998	Long distance	2	Fuel leak due to rupture of the injection line
1.15	25.4.	Volvo B10M	Wiima Finlandia	1985	Long distance	1	Injection pump switch breaking and delayed injection
1.16	30.4.	Volvo B10B LE	Ikarus EAG E94	2000	City	1	Exhaust pipe rupture

[2] 1 = Begining of a fire, extinguished by hand extinguisher.
2 = Limited fire.
3 = Uncontrolled fire, extended to passenger compartment.
4 = Vehicle completely burnt.

1.17	25.10.	Scania L94	Ikarus EAG E94	2000	City	1	Short circuit in the fan motor
1.18	25.5.	Scania K112	Ajokki Royal	1988	Charter	4	Loosening of the banjo connectot of the overflow pipe of the to the injection pump valve
1.19	2.6.	Setra S315H	Setra S315H	1995	Long distance	2	Overheating of the disk brake
1.20	2.6.	Volvo B10B LE	Carrus 204L-221	1996	City	1	Abrasion and short circuit of battery cable
1.21	17.6.	Volvo B10L	Carrus 204U	1995	City	1	Overheating of the disk brake
1.22	18.6.	Volvo B10B LE	Ikarus E94	2000	City	1	Overheating of the disk brake
1.23	19.6.	Volvo B10M	Ajokki Express	1987	Long distance	2	Short circuit in the electrical centre
1.24	19.7.	Scania K112	Delta Express	1985	City	1	Overheating of fan duct
1.25	30.7.	Neoplan	Neoplan N316K-Transliner	1993	Charter	4	Loose injection line compression joint and fuel leak caused by it
1.26	3.8.	Volvo B10B LE	Lahti 402	1994	City	1	Abrasion and short circuit of generator cable
1.27	5.8.	Scania K113	Ajokki Royal	1989	Long distance	3	Overheating of the drum brake
1.28	18.8.	Volvo B10B LE	Carrus City L	2001	City	1	Overheating of the disk brake
1.29	27.8.	Scania K112 CLB	Cutter Deca	1987	Long distance	1	Fracture of return pipe leading from the injection pump nozzle causing a fuel leak
1.30	4.9.	Scania K113 CLB	Lahti Falcon	1996	Long distance	1	Short circuit in fan motor of airconditioning duct
1.31	10.9.	Volvo B10M W2	Ajokki Royal	1986	Charter	4	Rear brakes pneumatic system leak caused overheating of drum brakes
1.32	10.9.	Volvo B10R-W67B	Wiima M304-110	1987	Long distance	1	Abrasion and short circuit of battery cable insulation
1.33	13.11.	Volvo B10LA	Carrus 204NU222	1996	City	1	Abrasion and short circuit of injection line led to fuel leak
1.34	22.11.	Scania K113	Carrus Delta	1991	Long distance	1	Short circuit in electrical centre
1.35.	25.11.	Volvo B10B LE	Wiima 204 L	1997	City	2	Abrasion of the heater wiring loom led to short circuit
1.36	3.12.	Scania K113	Lahti Falcon 540	1997	Long distance	1	Abrasion and short circuit of generator cable insulation
1.37.	4.12.	Volvo B10M	Wiima 202	1988	Long distance	2	Abrasion and short circuit of speed limitor wire
1.38.	19.12.	Volvo B10B	Carrus Fifty	1996	Long distance	2	Abrasion and short circuit of battery cable insulation

2 ANALYSIS

2.1 Vehicles

2.1.1 Distribution by model and type

In 2001 there were about 8 500 registered buses in Finland (including vehicles of 25 seats or fewer). The total number of buses was about 9 800.

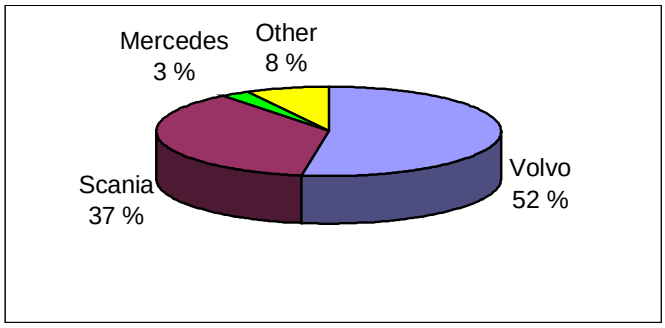

Diagram 1. Distribution of bus fire incidents investigated, by model, in 2001.

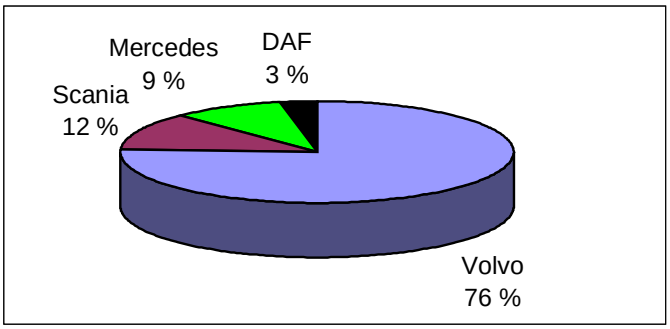

Diagram 2. Distribution of bus fire incidents investigated, by model, in 2000.

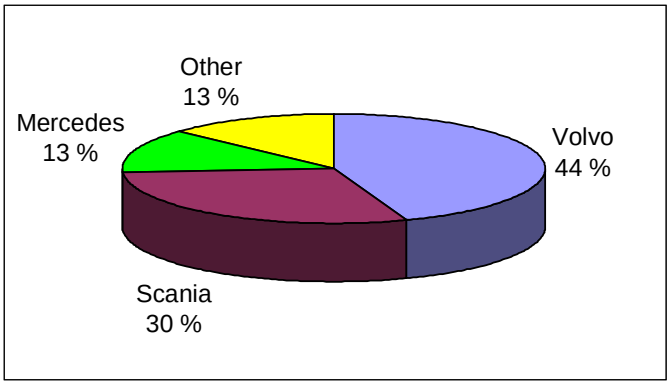

Diagram 3. Distribution, by model for buses registered under permit, 2001.

The most significant difference between the years 2000 and 2001 was a considerable increase in the fires of Scania vehicles compared to Volvo. The fire statistics for Volvo in

the year 2000 were characterised mainly by three types of fault, these were disk brake fires, the short circuits of the battery cable over the motor, and fracture of the fuel return pipe system. In 2001 there wasn't any fracture of the return pipe from the injection pump.

2.1.2 Age Distribution

In the fire statistics the average age of buses is 7.9 years and in 2000 the average age was 4.9 years. The oldest vehicle was a 1985 model and the most recent a 2001 model. Most fires (5 incidents) took place in 1988 and 1996 models.

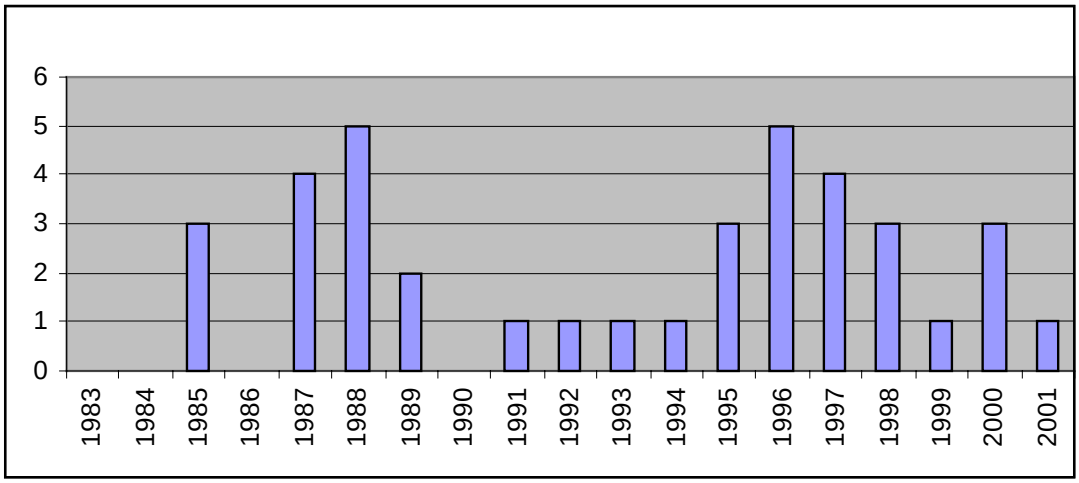

Diagram 4. Bus fire incidents investigated in 2001, by year of manufacture.

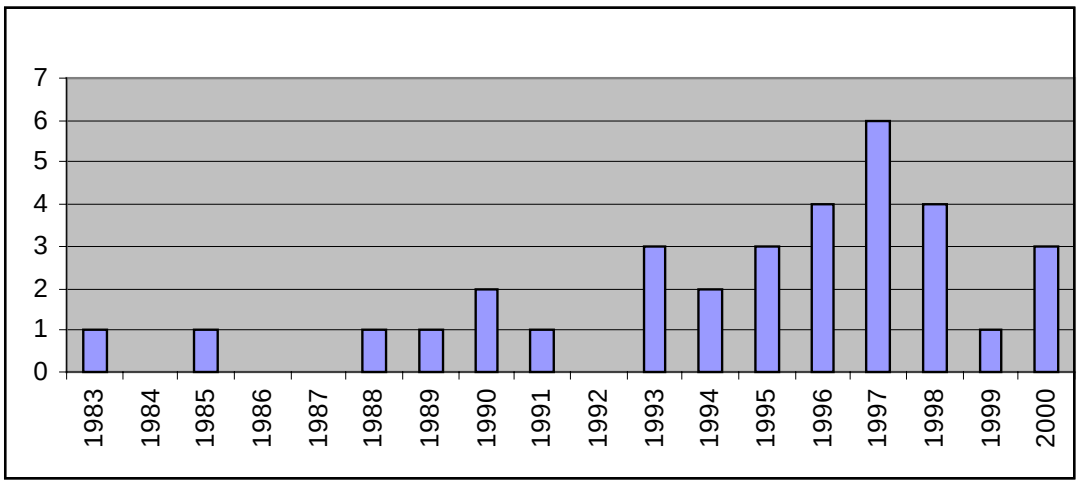

Diagram 5. Bus fire incidents investigated in 2000, by year of manufacture.

Vehicles had been driven an average of 670 000 kilometres, ranging from 1 460 to 1 800 000 kilometres.

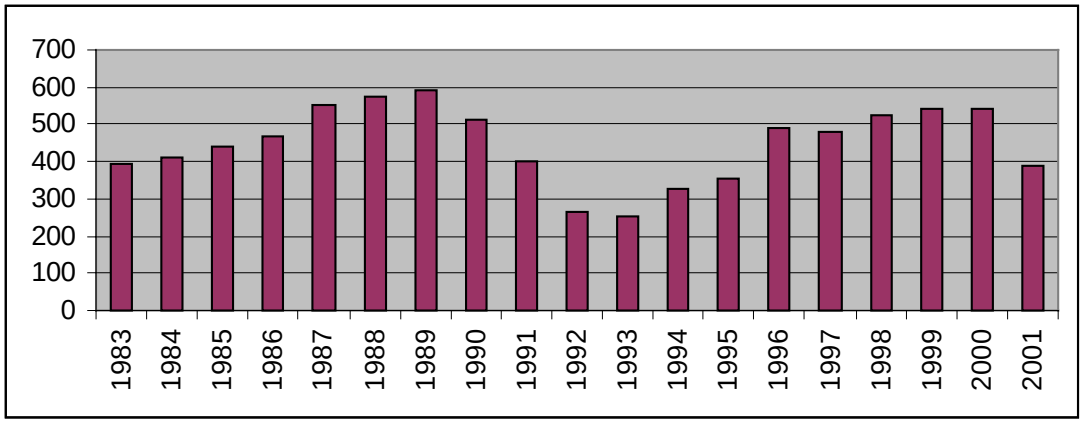

Diagram 6. Buses registered in the years 1983 - 2001.

2.1.3 Forms of traffic

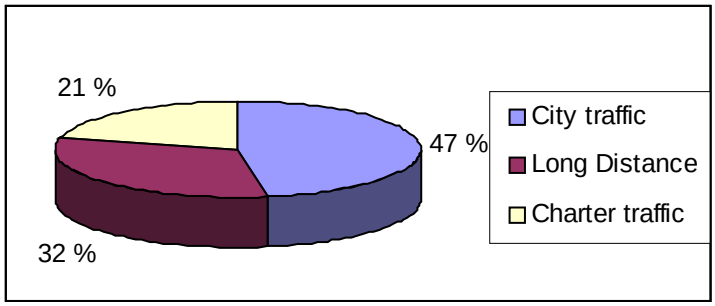

Diagram 7. Forms of traffic for fires in 2001.

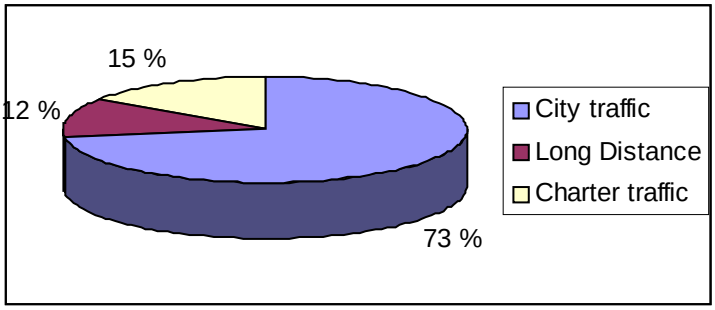

Diagram 8. Forms of traffic for fires in 2000.

Clearly the majority of incidents happened in city traffic as in 2000, but the amount has diminished. This has been affected by the fact that the proportion of Scania vehicles has increased and most of them were in use in long distance traffic.

2.2 Progress of the fire and passenger safety

2.2.1 Progress of the fire

A total of 30 fires started outside the passenger compartment, 17 of which started in the engine compartment, 9 in the brakes and 4 from under the body.

The most significant difference from the statistics for the year 2000 is the increase of the incidents which started inside the vehicle. In 2001 eight fires (incidents 1.4, 1.11, 1.12, 1.17, 1.23, 1.24, 1.30 and 1.34) began inside the vehicle but in 2000 there were only four. Three of the 2001 cases were fires in fans related to air conditioning and heating, three fires started in the electrical centre, one from fire in the wiring loom behind the dashboard, and one fire which started in the fluorescent lamp.

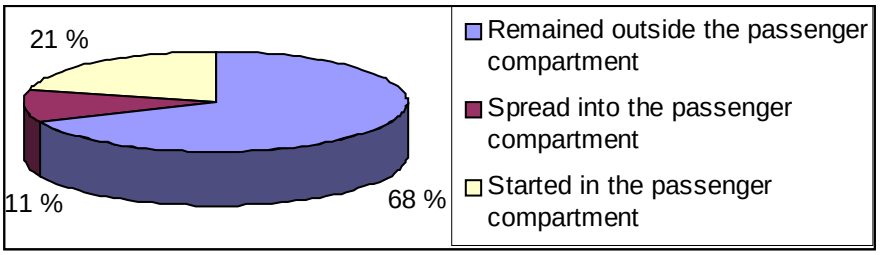

Diagram 9. Spreading of the fire, 2001.

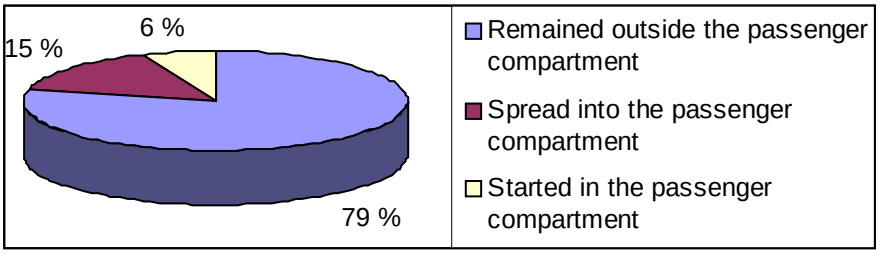

Diagram 10. Spreading of the fire, 2000.

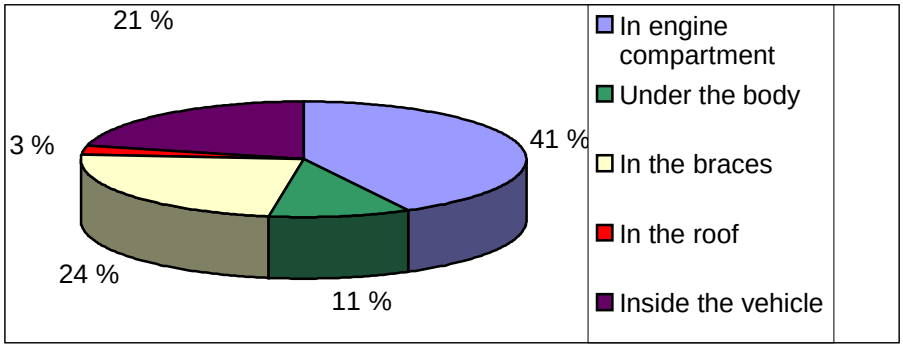

Diagram 11. Origins of the fire, 2001.

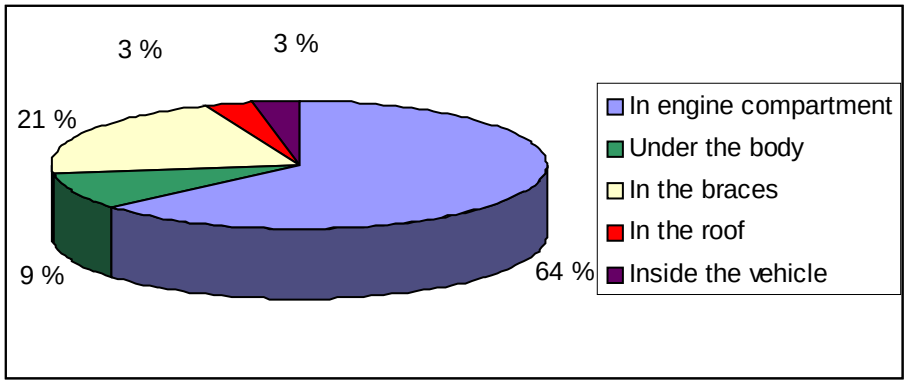

Diagram 12. Origins of the fire, 2000.

Four of the fires that started outside the passenger compartment spread to the passenger compartment. Three of the vehicles were destroyed beyond repair and one was slightly damaged. Furthermore, one of the vehicles in which the fire started in the passenger compartment was destroyed.

2.2.2 Passengers' evacuation

Three of the buses which caught fire were empty (in 2000 there was one[3]), only a driver was in 14 (9), five (3) buses had fewer than 10 passengers, and in three (7) buses there were 30 or more passengers. On average there were 20 (23) passengers. In the vehicles there were altogether a total of 406 (411) persons.

In all of the fire incidents there were no difficulties in passenger evacuation. The doors opened as normal, or a backup system was used and all passengers left on their own initiative.

The fire incidents showed that the fire resistance of the engine compartment was so good that there was enough time for evacuation. On the other hand, the statistics reveal that safe evacuation time varies greatly depending on the cause of the fire. The evacuation time is essentially influenced by whether the fire started from a short circuit or fuel leak, and how long the engine still continues to run during the time when fuel is injected into the fire. Fires started more slowly in those incidents caused by a short circuit than by a fuel leak.

Normally the fire moves into the passenger compartment from outside after the flames have broken through the window above the fire.

In the statistics are eight vehicles where the fire started from inside. Generally fires that start inside start from electrical equipment and are noticed immediately. However, in one case (1.12) the fire started in the roof lighting at the rear of the passenger compartment and not being noticed immediately it had time to light the inner fabric of the vehicle. There were two people in the front of the car at the moment the fire ignited. The fire extinguisher could not be used because of the intense smoke. Both persons had time to

[3] The number in parantheses refers to the corresponding statistic for the year 2000.

leave the vehicle but their luggage remained on their seats. The fire completely burnt out the passenger compartment.

From the point of view of passenger safety it is important that the buses contain at least two doors. In vehicles used in city traffic there are usually at least three doors. The doors are wide and the vehicles are the easy to use low entry buses. In single-door vehicles the fire can make use of the door impossible in which case the evacuation has to be made through the emergency exits i.e. the windows and hatches. There were no single-door vehicles in the incidents investigated. According to the present structure regulations buses are required to have at least two doors (Ministry of Transport decision on the structure of buses and equipment 29.6.1990/637).

Passenger numbers varied from zero to 40, the average being 20. On the basis of this study one can state that in the fires which had taken place passengers' safety was not at risk. However, the situation could change significantly if, for example, there are disabled passengers in the vehicle. The same conclusions were also reached for bus fires in the year 2000.

2.3 Fire extinguishing methods and results

2.3.1 First-hand extinguishing methods and results

First-hand extinguishing is defined in this context as the actions taken to extinguish a fire before the units of the rescue service arrived at the scene. Of the 38 recorded incidents (33 in 2000) it is known that the driver operated the fire-extinguisher in 32 (23) of them. In seven (3) incidents more than one dry powder extinguisher was used. In one incident a coat dipped in water was used as a first hand extinguisher. In six (4) incidents an extinguisher was not used.

First-hand extinguishing succeeded in 22 (17) incidents. The most common reason for failure was the premature discharge of the extinguisher's contents, i.e. the extinguisher's capacity was too small.

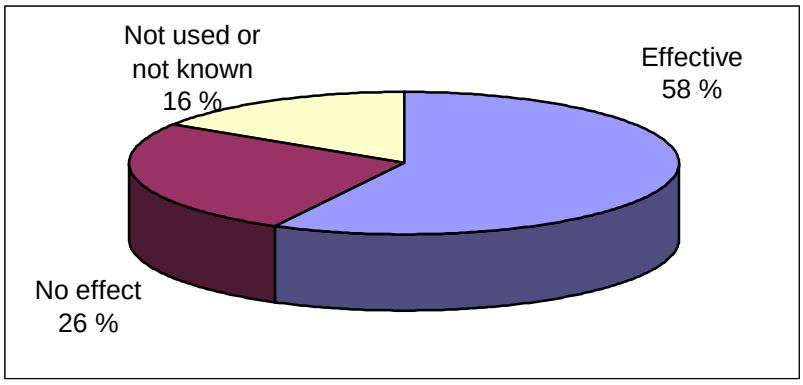

Diagram 13. First-hand extinguishing in 2001.

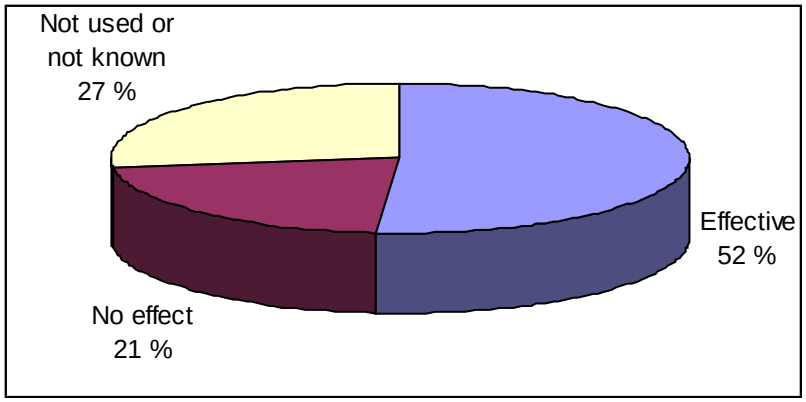

Diagram 14. First-hand extinguishing in 2000.

2.3.2 The significance of first-hand extinguishing

The speed and effectiveness of first-hand extinguishing is of crucial significance to the extent of the damage. In vehicle fires the first-hand extinguishing will nearly always become the driver's task.

In an urban area the rescue service units arrive at the scene of the fire quite quickly, usually in less than 10 minutes. In contrast, in rural areas the time of arrival of the fire fighters is usually distinctly longer. The incidents show that if the driver has not extinguished the fire, or has not prevented it from spreading, and the fire fighters' arrival time is more than 10 minutes, then the fire will already have moved to the passenger compartment. If the fire has started from inside the vehicle the significance of first-hand extinguishing is further emphasised.

In the statistics there were six disk brake fires that were all extinguished by the drivers using a dry powder extinguisher. In the two rear wheel drum brake fires the driver did not succeed in the extinction of the fire in which case the cars burnt beyond repair. These cases are a good example of the importance of the first-hand fire extinction.

2.3.3 The capacity and skill in using the extinguisher

In the analysis of bus fires for the year 2000 it was stated that a 2 kg capacity extinguisher proved to be too small in many fire-extinction situations. In other words the contents of the extinguisher were exhausted well before the fire was extinguished, or the fire had re-ignited when the extinguisher contents were exhausted. During the Bus Fire Project a few bus owners have changed the small fire-extinguishers for extinguishers with 6 kg capacity and have begun drivers' first-hand fire-extinguishing training.

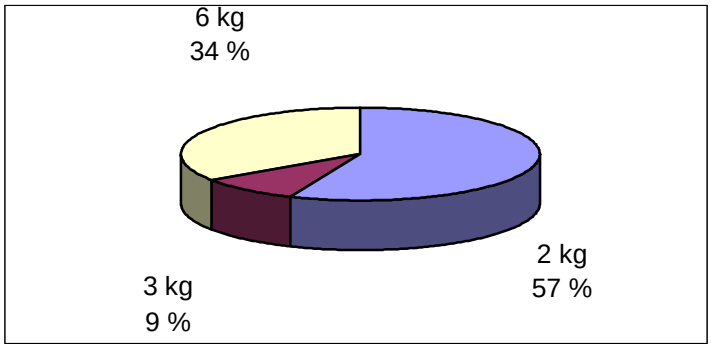

Diagram 15. The size of the fire extinguisher installed in vehicles, by incident, in those cases where the size of the extinguisher is known, for 2001.

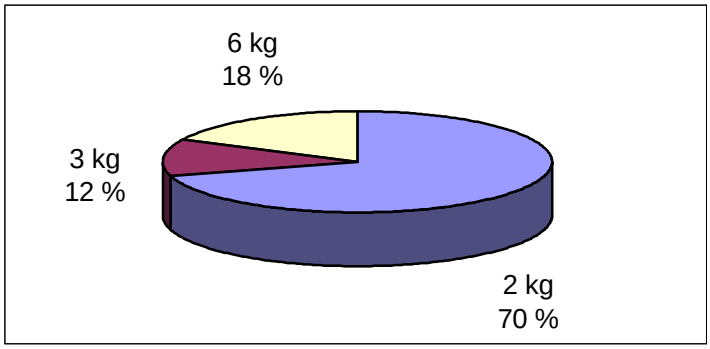

Diagram 16. The size of the fire extinguisher installed in vehicles, by incident, in those cases where the size of the extinguisher is known, for 2000.

In those incidents about which the size of the fire extinguisher is known there were 21 (15) instances of a 2 or 3 kg dry powder extinguisher, and 11 (4) instances of a 6 kg extinguisher.

The presence of even a large extinguisher will not put out a burning fire if it is not used, or not used properly. In the incidents investigated there were six (4) fires in which the driver did not use an extinguisher; and in one incident the extinguisher was absent.

The way the driver uses the extinguisher crucially determines the extent to which the fire damage is restricted. Bus company owners should therefore give every driver fire extinguisher training in which each trainee would be allowed to use the extinguisher. Personal extinguisher training increases the effectiveness of the extinguishing and lowers the threshold for the first-hand extinguishing. Drivers should also become acquainted with the structure of different vehicle types from the point of view of extinguishing fires. At the same time evacuation training should be given.

2.3.4 Fire extinguisher hole

Because of the small capacity of the extinguisher its contents have to be directed immediately at the source of the fire. To direct the extinguisher contents at the fire source the engine compartment cover often has to be opened posing a safety risk to the person fighting the fire. When the cover is opened, the fire gets oxygen and may spread beyond

the engine compartment. Furthermore, the effect of the fire extinguisher contents is at its best in a closed space. To direct the extinguisher contents at the source of the fire safely the engine compartment covers could be equipped with self closing extinguishing holes. The location of holes should be determined according to chassis and body so that the extinguisher contents can be directed freely at higher fire risk objects. Fire extinguisher holes like this have been successfully used in the engine guards of commercial aeroplanes of the piston engine era.

In one incident (incident 1.37) a fire began in the engine compartment of a vehicle with a centrally located engine, and there there were difficulties in turning it off. At the first hand fire-extinction stage the extinguisher contents were not directed to the target. In the fire-extinction two 2 kg and one 6 kg dry powder extinguishers were used. If at the first hand fire extinguishing stage the hatch in the floor of the cabin had been opened, the fire would probably have spread into the passenger compartment. In this type of fire a hatch and duct made for extinguishing and extinguisher contents would significacntly improve the efficiency of the first-hand extinguishing.

2.3.5 The fire fighters' part in the extinguishing of fires

Fire fighters were asked to attend 29 (21) incidents. The average time of arrival was 12 (11) minutes, the longest individual time being about 24 (50) minutes and the shortest being 57 seconds. In the Helsinki metropolitan area the time taken to arrive at the scene was on average 8.5 (6) minutes. In rural areas the length of time to arrive ranged from 10 to 24 minutes (15 - 50). In 15 (10) incidents only the securing and cooling of the extinguished fire remained the task of the fire fighters.

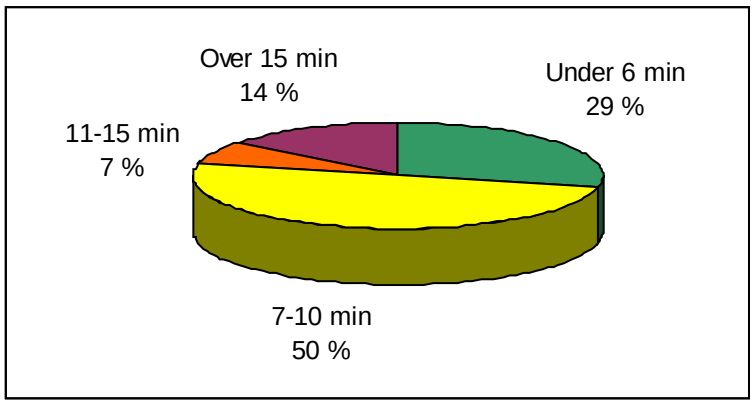

Diagram 17. Arrival time of the fire fighters 2001.

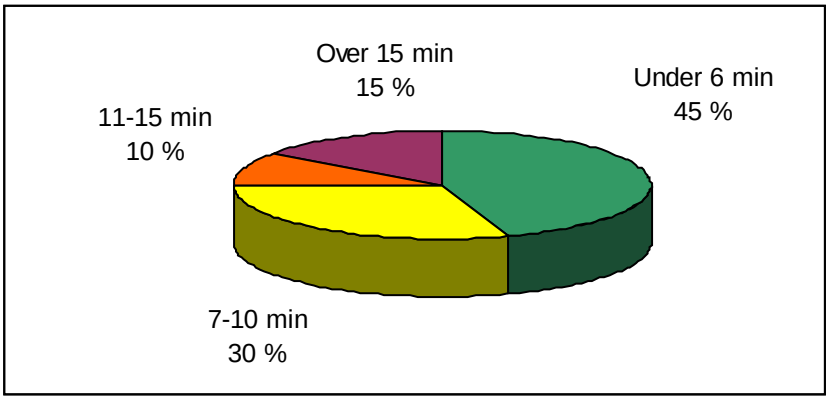

Diagram 18. Arrival time of the fire fighters 2000.

2.4 Fire warning system

The investigation's statistical system did not give complete detail on how many vehicles contained an alarm system but it probably was the case in nearly all vehicles. The drivers reported that it operated in four (4) cases. In the statistics there are 16 (21) incidents in which the fire spread from the engine compartment and which should have triggered the fire warning system. However, it is possible that the warning lamp functioned more often than has been reported because in many fire incidents short circuits and device failures caused by the fire lit up several indicator lamps on the dashboard. Also information about the fire engages the driver's concentration so much that all observations are not recalled. In older vehicles the fire warning system may also be non-functional.

The bus chassis manufacturers provide fire warning systems for the engine compartment and require that the system is installed according to instructions. The system includes three temperature sensors, a wiring loom, supervision electronics and a warning lamp with audible signal in the dashboard. In the statistics the Volvo B10B chassis was the most common. The cylinders of the engine are in a horizontal position in this model, so the engine is low. Thus this chassis is the most common in the low entry buses of city traffic. These engines have been equipped with three fire sensors which are fixed to the wiring loom of the engine. One of the sensors is for higher temperature. However, this "hot end" sensor has been placed on the side of the engine where there are two other sensors. This accounts for the fact that, for example, a fire which has started as a consequence of the breaking of the injection pipe is not initially detected by the fire warning systems. To ensure a more perfect range the "hot end" sensor should be placed near the cylinder head in which there are, among others, an exhaust manifold, exhaust turbine, injection pipe and turbo lubricating pipe.

2.5 Fixed fire extinguisher systems

Fully automatic or semi-automatic fixed fire extinguishing systems have been developed for vehicles. Not a single burnt vehicle had these fire extinguishing systems. Of the fires 16 representing 42.1% (21 representing 63,5%) started in the engine compartment, so

one can justifiably assume that the system would have put out all or the majority of these fires.

Fixed fire extinguishing systems in buses are extremely rare in Finland but they are used, among others, in forestry machinery.

The extra cost of the system installed in a new bus adds about 1% to the purchase price, so the obstacle to the decision to acquire one is probably based on an ignorance of the real costs of the system. The passive attitude of insurance companies to the acquisition of the system has not been likely to promote its general use either.

3 CAUSES OF THE FIRES

The causes of the fires can be roughly divided into five categories: fires caused by brakes, short circuit in battery or generator cable, other electrical equipment failure, fuel leaks and other causes. With respect to fires in the year 2000 what was new was that there were fires which started in the additional heaters, and there were three of these. The absence of additional heaters from the statistics for the year 2000 is probably due to the fact that the statistics were begun only in August. The fires which started in additional heaters in the year 2001 took place took place in January and February.

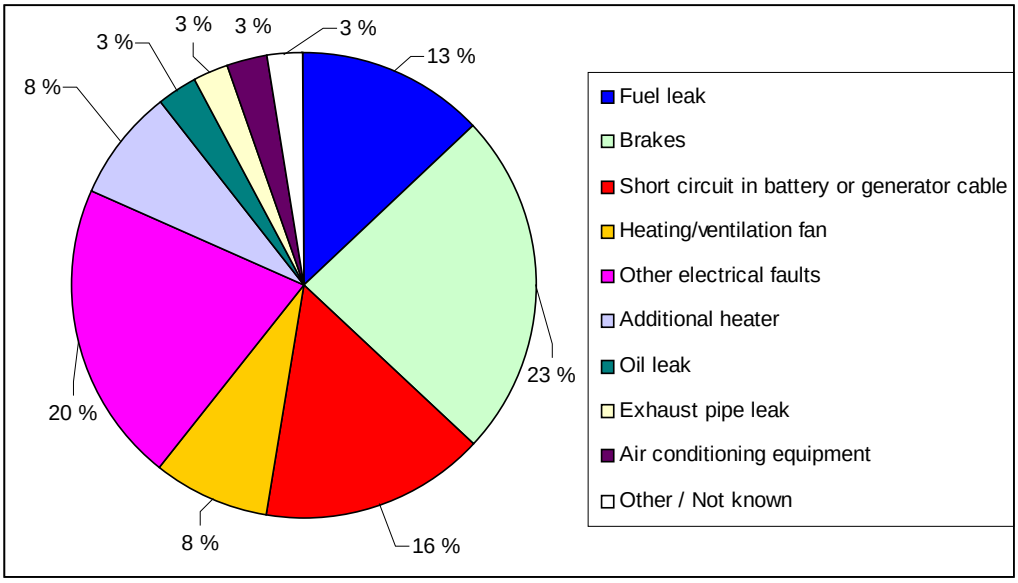

Diagram 19. Causes of the fires 2001.

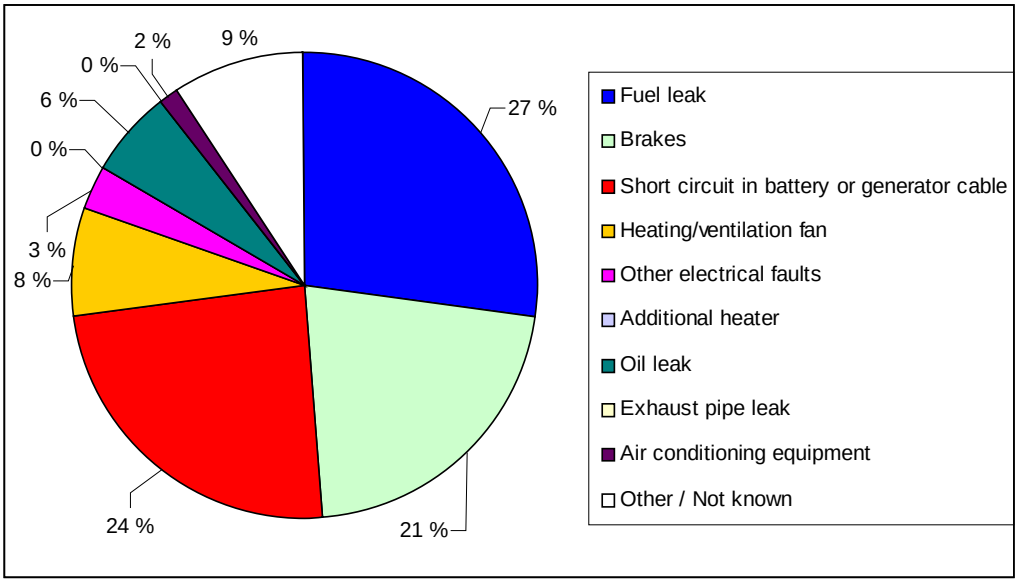

Diagram 20. Causes of the fires 2000.

3.1 Fires caused by brakes

In the statistics the largest group was fires caused by the overheating of brakes. In six (6) incidents fires started from overheating of disk brakes and three (1) from overheating of the drum brake.

The cause of drum brake overheating is usually the wearing out of the brake linings and drums so much that the S-cam (or Z-cam) turns too far and stays in the braking position. Of these there were two. In one (incident 1.31) the brake drum and brake linings were in good condition. In the case in question there had already been reduced pressure on the surface of the rear brake earlier whilst driving. Apparently there was a leak in the pneumatic system of the brake which caused the parking brake to engage.

As in 2000 there were six disc brake fire in 2001. The research explains that the fires from the disc brakes in question have taken place in city traffic in which brakes are used a lot and the cooling periods remain short. As a consequence of heating the brake pads do not retract sufficiently, but they continue to drag and the heating continues. Overheating consequently ignites grease or oil from the wheel hub. If the fire is not quickly extinguished, it can spread into the tyres and structures of the chassis. In all incidents the driver managed to put out the fire with a fire extinguisher. Jamming of the disc brakes is an obvious type failure which chassis and brake manufacturers have tried to find a solution; however they have not completely succeeded in this and development work is ongoing.

Front brake jamming causes drag which the driver usually notices. If there is steering drag, the driver has always to check the reason before continuing to drive. In addition to jamming of the brake, other serious reasons for steering drag are, among others, a puncture, damage to bearings and the malfunction of steering equipment, all of which require interruption to driving. These points should be brought up in driver training.

3.2 Short circuit in the battery and generator cable

A short circuit in the battery or generator cable was the reason for fire in six (8) cases.

Of these three (3) fires were caused by abrasion of the starter motor cable against the hoist bracket of the engine (incidents 1.20, 1.32, 1.38). As stated in Volvo's previously mentioned maintenance and overhaul notice for the fuel system (published 22.11.2000) "*In connection with the inspection of the fuel system the condition of the existing cables in the engine compartment, their location and fastenings must also be checked so that abrasion has not occurred*." The instruction given probably refers to the year 2000 and the aforementioned short circuit incidents happened prior to that.

Three fires were caused by abrasion of the generator cable: one against a hydraulic hose strenghtened with steel wire net, one against a bracket in chassis, and one in a connection in the wiring loom.

Of the repeated causes of fire that were found in the investigation of the year 2000 one was the abrasion of the battery cable against the hoist bracket of the engine. In 2001 there were still three fires caused by this. In the 2000 report this problem was clearly highlighted so it is surprising that this fault, which can quite easily be repaired, has not disappeared.

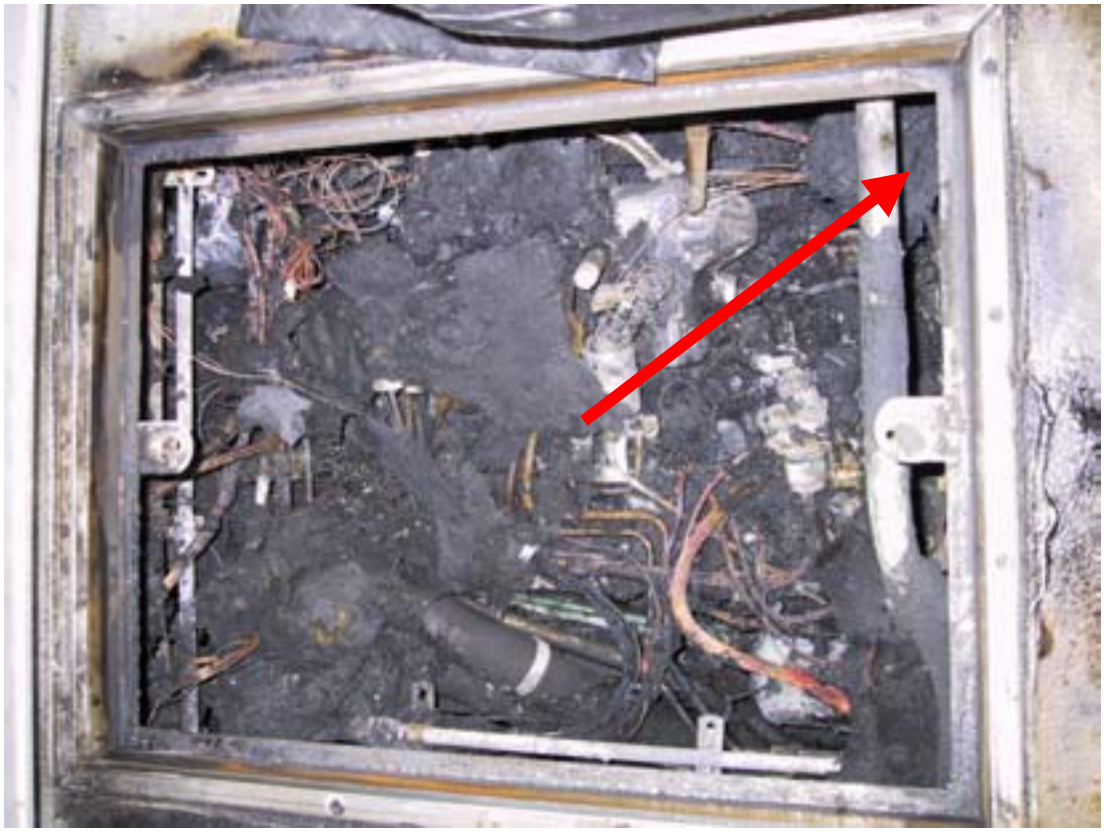

Figure 1. Typical damage after the abrasion of the battery cable against the hoist bracket of the engine (Volvo B10B). The arrow points to the location of the short circuit.

Figure 2. Protection and tightening of the battery cable at the repair shop. The wiring loom has been protected from abrasion with protective tubing and supported well. (Photo : Oy Pohjolan Liikenne Ab)

Figure 3. The tightening of the cable in Volvo's new production. The hoist bracket is below the tightened cable. (Photo : Volvo Ab)

3.3 Other electrical equipment failure

Of all the incidents in 2001 three temmed from the electrical centre: one was a fire in the wiring loom that began behind the dashboard and one was a fire that began in the fluorescent lamp. Two fires were caused by the abrasion of the wiring loom on the chassis, and one was a short circuit of the attachment bolt of the starter motor cable with the cover of the starter motor.

3.4 Fuel Leaks

Fire in five (9) incidents was caused by fuel leaks in the fuel system. The injection pipe broke in one (5) incident (incident 1.14). The line was into number 4 cylinder. One (1) injection pipe began to leak as the consequence of the wearing out of the pipe (incident 1.33). In one incident a temporary compression joint of the injection pipe had begun to leak.

In addition to the breaking of the injection pipe, one (3) fire was caused as the consequence of the fracture of the return pipe from the pump into the fuel tank (incident 1.29). Furthermore, one fuel leak resulted from the slackening of the joint (incident 1.18).

In 2001 there was no characteristic fracture of the arrival and return pipes of the fuel pump of the motor in any of the Volvo B10B, B10L and B10M models. The use of flexible pipes has probably had an effect here. Fuel leaks which had appeared in the additional heaters were the reason for three fires and these have been dedcribed in more detail in section 3.5.1.

3.5 Other reasons

3.5.1 Additional heater faults

Faults in the additional heater led to three fires during January and February. The reason for the fires was a fuel leak in the fuel pipes of the additional heater from which the fuel was able to flow to the exhaust pipe of the heater. The slackening of the pipe joint had taken place probably during a warm season when the heater had not been used. The leak often happens at the joint of a nylon and metal pipe.

3.5.2 Heating and air conditioning faults

In 2001 three fires started from the air conditioning and heating. In 2000 two fires began in the heating fan, and one in the air conditioning system in the roof of the vehicle, from its fan or in the roof fan duct.

Research has noted that in certain air fan types the electric motor speed series resistor has been installed in a fan casing made of plastic. When a fan ages and the bearings stiffen the fan's motor requires more current, and because of this the temperature of the resistor increases. With the stiffening of bearings the rotational velocity of the fan re-

duces and cooling of the resistor decreases. As a consequence the resistor's temperature rises and the plastic case of the fan catches fire.

The roof ducts and the heating pipe systems are often very dusty in older vehicles so, if the electric motor overheats or sparks, a fire can easily start and spread quite quickly. Special attention should be paid to the maintenance of electric motors, and to the cleaning of ducts and the maintenance of their filters. As vehicles age, attention should also be paid to the fact that the life of electric motors is limited and the motors should be renewed frequently enough.

3.5.3 Oil leaks

One (2) fire was caused by an oil leak in 2001. Engine oil from a broken turbo shaft reached the engine and ignited.

3.5.4 Injection timing changes

In one incident the breakdown of the operating switch of the injection pump caused incorrect injection timing. It caused the fire, because the injection was delayed. The motor and motor state overheated so much that the plastic parts of the motor state caught fire.

3.5.5 Exhaust Pipe Leaks

In one case the fire was caused by the exhaust pipe leak between the turbo and the silencer. Hot exhaust gases lit the sound insulation of the motor compartment.

For the same reason fires have also started earlier because the ground clearance of a low entry bus is small and, for example, the kerb of the pavement is easily hit by the silencer below. In that case the fastening of the silencer will be damaged, the position of the silencer changes and the flexible part of the pipe breaks.

3.5.6 Air conditioning faults

One fire started in the roof in the air conditioning equipment. The cause of the fire is unclear as it continued on its journey when the fire had been extinguished (it was a Russian bus).

4 CONCLUSIONS

1. Passenger evacuation proceeded in all incidents without risk to passenger safety. The passenger numbers in the incidents investigated varied from zero (0)[4] to 40 (58), the average being 20 (23). There were altogether 406 (411) passengers in the vehicles.

2. In 22 (17) incidents the first-hand extinguishing by drivers prevented severe fire damage or complete destruction of the vehicle.

3. In one incident the hand extinguisher was missing.

4. Of all fires 42% (64%) started in the engine compartment.

5. Not one single bus contained an automatic fire extinguishing system in the engine compartment.

6. An automatic fire extinguishing system installed in a new vehicle costs 1% of the purchase price of the vehicle.

7. Fire alarm sensors had not been located correctly in all incidents. In several vehicles the fire alarm sensor in the engine compartment had not been installed close to the engine's cylinder head, from which several fires had started, for example, when the injection pipe broke.

8. Some causes of fire were repeated several times: jamming of disc brakes, breaking of fuel pipes, and abrasion of the battery and generator cables, although through the 2000 report people have been informed about these in relevant journals, and in various lectures and training events.

9. In the incidents investigated the average age of buses was about 8 (5) years, driven on average 670 000 (430 000) kilometres

10. The time taken for the fire fighters to arrive at the scene of the fire was about 8 (6) minutes in the Helsinki area.

11. Of all fires 47% (73%) took place in city traffic.

12. In the most serious incident (incident 1.18) the driver continued to drive, despite noticing fuel leaking from the engine. In the vehicle were 40 passengers, of which a large majority were day-care age children.

[4] The number in parantheses refers to the corresponding statistic for the year 2000.

5 RECOMMENDATIONS

5.1 From recommendations made in Incident Report D 1/2000 Y, Bus Fires in Finland during 2000

All new buses should be equipped with an automatic or semi-automatic fixed fire extinguisher system. [D1/00Y/S1]

Investigators recommend that the Ministry of Transport and Communications should prescribe a fire extinguisher of at least 6 kg in buses instead of the current 2 kg hand extinguisher. [D1/00Y/S2]

Bus manufacturers should equip the engine compartment covers with holes for fire extinguisher nozzles, with a spring loaded lid that opens inwards. The location of the holes should be determined according to chassis and body so that the extinguisher contents may be freely directed to higher fire risk objects. The lid should be equipped with the picture of a hand extinguisher. [D1/00Y/S3]

Bus company owners should give every driver training in the first-hand extinguishing and at regular intervals arrange practice in the use of fire extinguishers and passenger evacuation. [D1/00Y/S4]

The bus company owners should give the drivers training in the type of equipment to be used. Drivers should become conversant with the function, among others, of the vehicle's fire warning system and the indicators relating to it. The drivers should always read the vehicle manual carefully when the vehicle type is not familiar to the driver. [D1/00Y/S5]

In driver training the importance of observing the driving properties of the vehicle should be emphasised. If, for example, there is steering drag, the reason for it has to be determined before continuing to drive. There can be several serious reasons for steering drag, one of which is the jamming of the brake and its overheating. [D1/00Y/S6]

Importers should compile statistics on fires in bus models that they represent. They should draw conclusions from them and should prepare a work update guide for prevention of similar fires. [D1/00Y/S7]

The vehicle user should take care of:

- *maintaining cleanliness of the engine and engine compartment*
- *inspecting the condition of the fuel pipes and replacing them with new types of pipes if necessary*
- *undertaking fitting work, according to the instructions in the maintenance manual, by taking into account the correct torque in tightening and the support of pipes*
- *checking the fitting and condition of the battery and generator cables according to the scheduled maintenance service program. [D1/00Y/S8]*

The bus company owners should add to their own scheduled maintenance service program the fire safety guide "Bus and Trucks, Fire Safety Guide, 1999" drawn up by the Federation of Finnish Insurance Companies (Vakuutusyhtiöiden keskusliitto) and Insurance Group's Vehicle Repair Commission (Vakuutusyhtiöiden autokorjaustoimikunta) and implement its vehicle fire safety inspection form in Appendix 3. [D1/00Y/S9]

Soundproofing and heat insulation components in the engine compartment, or their surface materials, should be fire resistant. [D1/00Y/S10]

One of the fire alarm sensors should be placed close to the cylinder head of the engine on the so-called 'hot side'. [D1/00Y/S11]

5.2 Additional heating maintenance before use

In January - February additional heaters led to 3 fires. The causes were a fuel leak in the heater pipe.

The additional heaters and their fuel pipes should be checked before the beginning of the heating season. The inspection should be added to the maintenance system of the vehicle. [D1/01Y/S1]

5.3 Injection Line repair

In one incident the reason for the fire was a leak of the temporary compression joint in the injection pipe. It is common practice to regard this temporary repair as permanent rather than transfer the vehicle from the place of damage to the repair workshop.

The use of an injection pipe that has been repaired with a compression joint should be restricted to transfer the vehicle to the repair workshop where the pipe has to be changed for a pipe that is suited for the purpose. [D1/01Y/S2]

REFERENCES

The following references are filed in the Accident Investigation Board. Please note that the originals are published only in Finnish. Translation of publication titles here is merely for the convenience of the reader.

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