ROAD ACCIDENT OCCURRED ON 02/28/1996. COACH BURSTS INTO FLAMES IN BAILÉN (SPAIN) Chapter 08. COACH EVACUATION DRILLS.

INSIA (UNIVERSITY INSTITUTE FOR AUTOMOBILE RESEARCH)

December, 1996

Resume prepared by, Mr. Javier Páez and Mr. Arturo Furones, Mr. Enrique Alcalá (March, 2018)

CONTENTS

1 DESCRIPTION OF THE EXITS AVAILABLE IN THE VEHICLE.

The specifications of the existing exits in the accident vehicle come from the homologation report of this vehicle, carried out by the Institute of Applied Automobile Research (IDIADA). Most of this information cannot be corroborated on the vehicle, due to the high degree of deterioration caused by the fire in it.

This information has been provided by the company CARROCERÍAS NOGE S.L.

1.1 Location of the exits.

The coach vehicle has nine exits. Regulation 36.02 prescribes a minimum number of six departures in Class II vehicles with more than 35 seats, so that this vehicle comfortably meets this specification.

The distribution of these exits in the vehicle are shown in Figure 1, these exits presented the characteristics described below.

1.1.1 Side windows

There are three side windows prepared as emergency exit windows, with dimensions such that they can be computed as double exits. Their situation in the vehicle is as follows:

- One, on the right side.
- Two, on the left side.

Therefore, these windows add up to six exits. The height between the lower edge of the side windows and the floor is 625 mm.

1.1.2 Rear windshield.

There is one exit located on the rear windshield. This exit allows to comply with the compulsory existence of exit in one of the following locations:

- Front face.
- Rear side.
- Roof.

This window is not computable as double exit, and therefore counts as a single emergency exit. The height between the lower edge of the side windows and the floor is 700 mm.

1.1.3 Service doors.

There are two service doors equipped with the devices prescribed by Regulation 36.02 to be considered as exits, and located both on the right side and computable as individual exits.

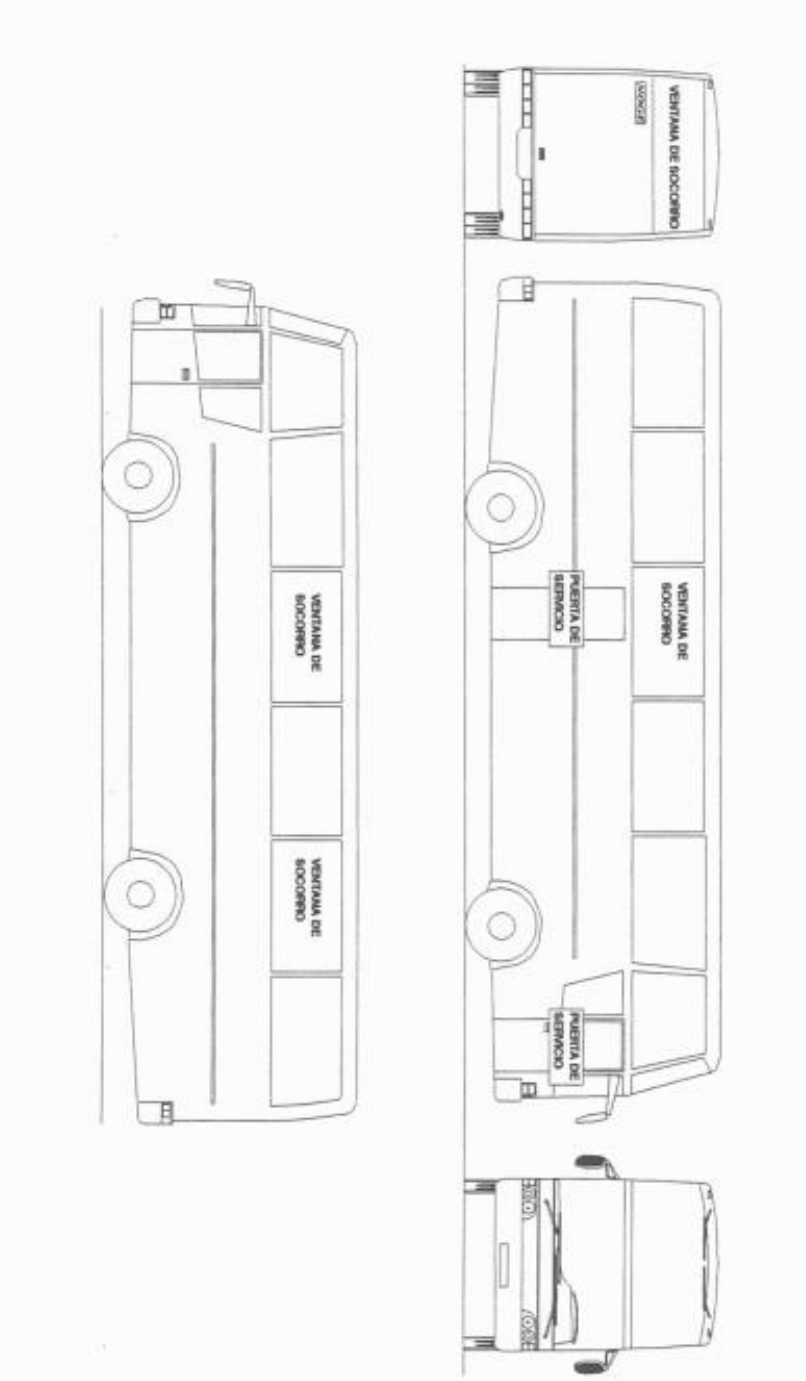

Figure 1: Location of exits on the bus

1.2 Dimensions.

The dimensions of exits are considered as relevant factors for the evacuation of the vehicle. The dimensions of these exits are shown in the following table (Table 1).

Table 1: Vehicle exits dimensions

Type of exit	Height (mm)	Width (mm)
Side Windows	1050	1760
Rear Windshield	610	Down: 2070 Up: 1950
Front service door	1760	725
Rear service door	1770	760

Simultaneously, the influence of the exit access configuration such as the rungs of the footrests and the corridor is also remarkable. The dimensions of these elements are shown in the following table (Table 2). There is not installed any retractable step.

Table 2: Dimensions (mm) of the rungs and corridor of the coach vehicle.

Type of exit	Height (mm)	Width (mm)	Depth (mm)
Front stair			
1er step	390	390	320
2º step	535	250	220
3er step	700	225	-
Rear stair			
1er step	760	390	305
2º step	690	285	220
3er step	650	290	210
4º step	650	290	280
5º step	Gangway	250	500
Corridor access stair			
1er step	Corridor	210	205
2º step	-	215	205
3er step	-	215	Corridor

1.3 Technical requirements

1.3.1 Emergency exits.

The vehicle emergency exits are windows distributed around its perimeter, and designed to be broken in case of emergency.

1.3.1.1Front windshield

The front windshield can never be a rescue exit by means of glass breakage, due to the fact that the current national legislation requires that this windshield be laminated (Triplex).

This glass is manufactured according to a "sandwich" type structure, consisting of two floating crystals of 3 mm thickness each, separated by a 0.76 mm thick layer manufactured by Monsanto or by Dupont. The windshield assembly is moulded and made by Nordlamex from Finland.

1.3.1.2Rear window

The rear window is one piece tempered glass, manufactured by Manufacturas Tarrida S.A., from raw material from CRISTALERA ESPAÑOLA.

The manufacturing is carried out on rollers and the tempering is done by air, by means of the red glass system suspended by clamps, on which nozzles act which cause the sudden drop in temperature.

The rear windshield approval password is: E9-43R-00.0374. The specifications of this crystal are the following:

- Commercial name: VIDUR
- Nominal thickness (thickness category): 5 mm (III)
- Tempering nature: thermal.
- Colouring of the glass: green.

1.3.1.3Side Windows

The side windows are also tempered, and each window is a single piece. The glasses are manufactured by Manufacturas Tarrida S.A. The approval password for the side windows is: E9-43R-00.0408. The specifications of this crystal are the following:

- Commercial name: CLIMALIT
- Nominal thickness (thickness category): 5 mm glass / 8 mm air chamber / 5 mm glass.

- Tempering nature: thermal.

1.3.1.4Rest of side windows

The remaining side windows are not subject to specification by Regulation 36.02. However, these windows usually meet the same specifications as the side emergency windows to facilitate their destruction in case of emergency.

1.3.1.5Hammers

Next to each emergency window, a hammer should be provided to break the glass for easy identification and accessibility, which means a total of four hammers.

The following illustration (Figure 2) shows the location of one of these hammers. This photograph has been taken on a vehicle identical to the damaged vehicle.

Figure 2: Photograph of hammer in an identical vehicle to the damaged one.

1.3.2 Service doors.

The service doors are manufactured by the company BODE-MASATS S.A. These doors have remote control, with pneumatic drive from the driving position.

At the same time, in each one of them there is an internal emergency opening command and an external one, without exceeding this control of the wall on which it is located.

Finally, and to ensure locking, these doors are equipped with an anchor driving by a mechanical device.

There are no emergency doors in this vehicle.

1.3.2.1Description of the operation of the service doors.

The operation of the service doors is pneumatic. The opening and closing operations are based basically on the safety of the passengers, from two points of view:

- Avoiding accidental opening of doors during movement.
- Encouraging opening in case of disaster.

The operating mechanism of the service doors is shown in Figure 3.

The basic elements of this mechanism are:

1. Double acting cylinder, double damping, with spindle. The cylinder is responsible for the movement of rotation and vertical translation of the door. An outline of it is presented in Figure 4.
2. Anchoring upper and lower wedges. These wedges ensure the blocking of the door, while there is air pressure in the pneumatic circuit. An outline of them is presented in Figure 5.

The operating scheme of the service doors is presented in Figure 6.

3. As shown in the Figure 6, and starting from the open door position (upper graph), the cylinder rotates the door around the pivot arm (reference 5952B115, Figure 3). When this is placed on the frame, the cylinder performs a second movement of vertical upward translation and effect the anchoring of the wedges. The cylinder drive is pneumatic. This drive method ensures the anchoring of the door while there is air in the pneumatic circuit.

4. When activated the emergency controls, the pressure in the two chambers of the cylinder is equalized, so that it descends vertically and the door is unlocked, allowing it to be opened without difficulties.

The blocking of the doors by pressure of the vehicle occupants from the inside while those are descending is quite difficult due to the weight of this door (40-50 kg) together with the preload of the spring located in the upper part of the pivoting bar (≈ 60 kg), which adds a total downward force of 100-110 kg.

As shown in Figure 6, the tension bar (RBT) has the same radius of rotation as the arm (RB), which ensures that the door moves parallel to the body.

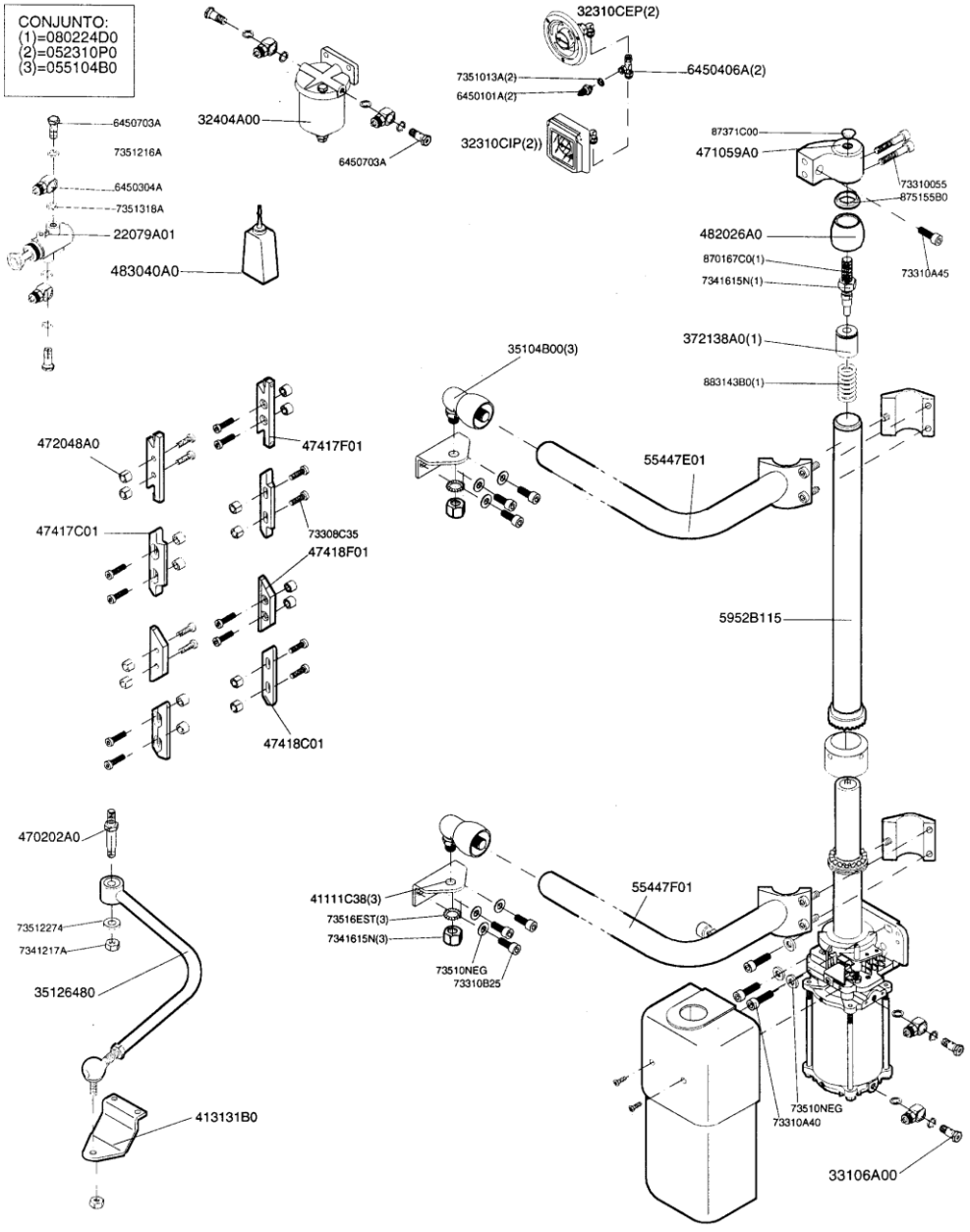

Figure 3: Operation Mechanism of the service doors.

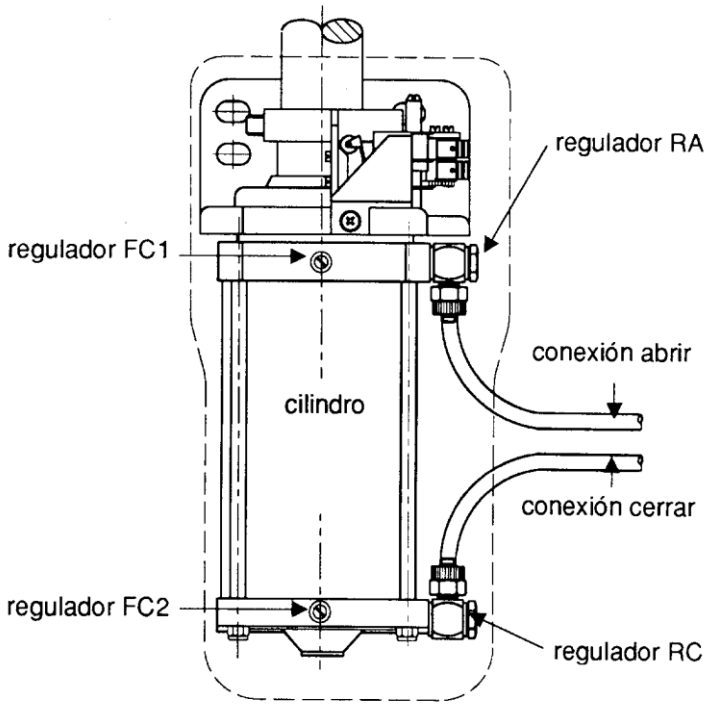

Figure 4: Double acting cylinder, double damping, with spindle, for operating the service doors.

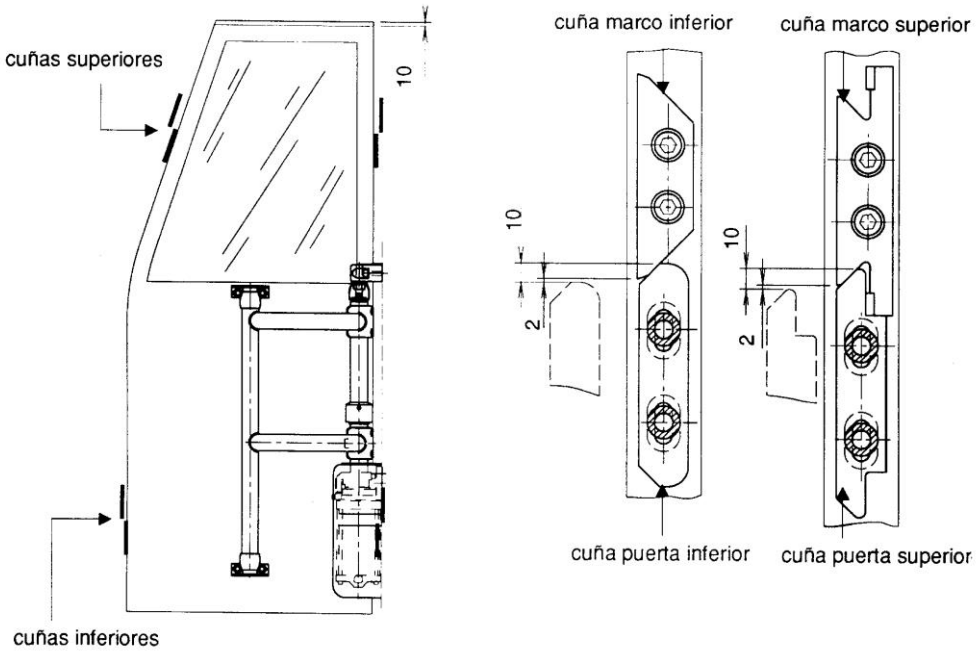

Figure 5: Anchoring wedge of service doors.

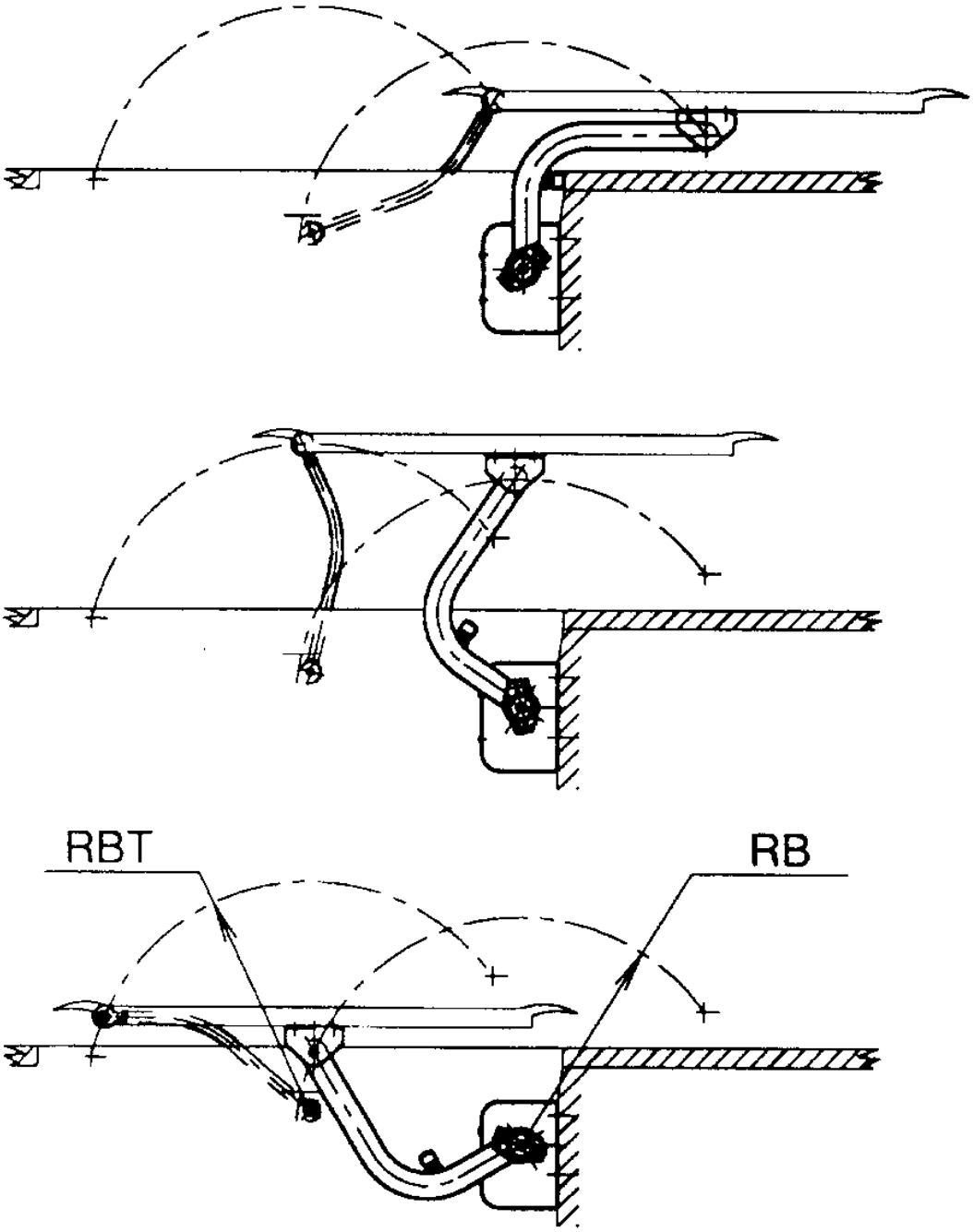

Figure 6: Scheme of the service doors operation

1.3.2.2Description of the emergency opening controls.

The driver has a general emergency control located on the driving panel. This control releases the anchoring of the service doors, while fulfilling other missions such as: closing the passage of fuel to the engine, cutting off the power supply from the batteries, etc. On the other hand, the emergency opening controls available to passengers are push type, for manual operation by simple pressure with the fingers. The push buttons are responsible for the control of solenoid valves located on the control module. This button is protected differently depending on its location on the coach vehicle.

The external controls of the doors are of the commercial type 32310CEP. This command is presented in the following figure (Figure 7).

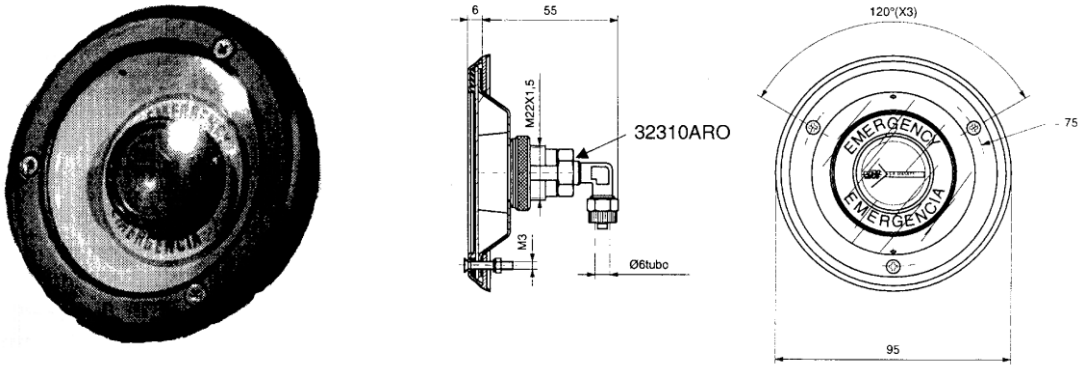

Figure 7: External emergency opening control of service doors.

These external controls are protected from atmospheric agents by a flexible plastic material cover, which allows their operation by simple manual pressure.

The external control is located at a maximum height of 1800 mm, in compliance with the technical specifications of Regulation 36.02.

The interior controls of the doors are of the commercial type 32310CIP. This command is presented in the following figure (Figure 8). These internal controls are protected from unintentional operation by a rigid plastic cover, which must be lifted to access the push button.

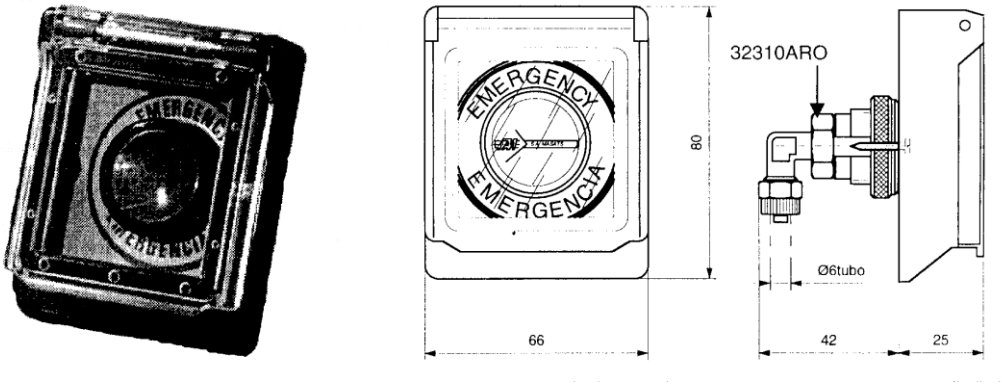

Figure 8: Internal control of emergency opening of service doors.

The position of the internal controls is not contemplated by Regulation 36.02 in force at the moment of the homologation of this vehicle, so that its location has no influence on the final result of the homologation report.

However, if we abide by the current Regulation in force (Regulation 36.03), which does not affect the homologation of the damaged vehicle, the position of *the* internal controls should meet the following specification:

> *"5.6.5.1.2 In the case of an internal control, placed at a distance of 300 mm or less from the door and at a height not lower than 1600 mm above the first step"*

According to this specification, the damaged internal controls of the vehicle are inadmissible since they are located at a height of less than 1320 mm above the first step.

It is noteworthy that these controls inside the passenger compartment are not equipped with any type of emergency lighting, so their location is very difficult in the case of a failure of the inner illumination.

Finally, a set of illustrations is shown where you can see the location of the emergency opening controls of the service doors, as well as the accident vehicle, as in a vehicle identical to the accident.

Figure 9: External control location on the front door (vehicle identical to the accident).

Figure 10: External control detail on the front door (vehicle identical to the accident).

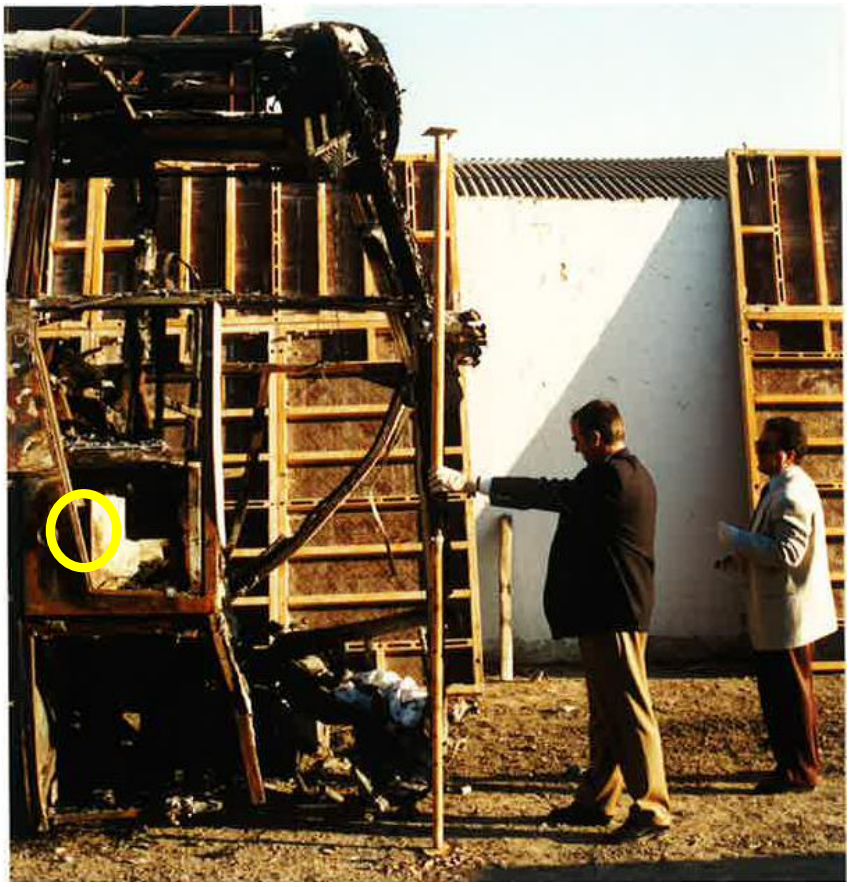

Figure 11: External control location in front door (accident vehicle).

Figure 12: Detail of external control in front door (accident vehicle).

Figure 13: Location of internal control in front door (vehicle identical to the collided one).

Figure 14: Location of internal control in front door (accident vehicle).

Figure 15: Detail of exterior control in the rear door (vehicle identical to the collided one).

Figure 16: Detail of external control in rear door (accident vehicle).

Figure 17: Location of internal control in the rear door (vehicle identical to the collided one).

Figure 18: Detail of interior control in rear door (vehicle identical to the collided one).

Figure 19: Detail of interior control in rear door (accident vehicle).

1.3.2.3Actuation of the emergency opening controls

The emergency control is in charge of releasing the anchoring of the service doors, to allow the exit of passengers in the event of an accident.

To do this, the emergency controls pneumatically control the solenoid valves, located in the control module, which equalize the pressure in the two chambers of the cylinder responsible for the rotation and translation of the doors. After this, the doors perform a vertical descent movement which the door is unlocked with, and can be moved manually without difficulty.

This action of safety of the emergency controls is possible while these doors are not blocked externally by the mechanical locks, described below.

1.3.2.4Description of the mechanical locks of the service doors

The mechanical locks of the service doors have the mission of ensuring the blocking of them in the absence of the driver and passengers. This locking can only be operated from outside the vehicle.

The operation and location of this locking system is shown in the following figure (Figure 20).

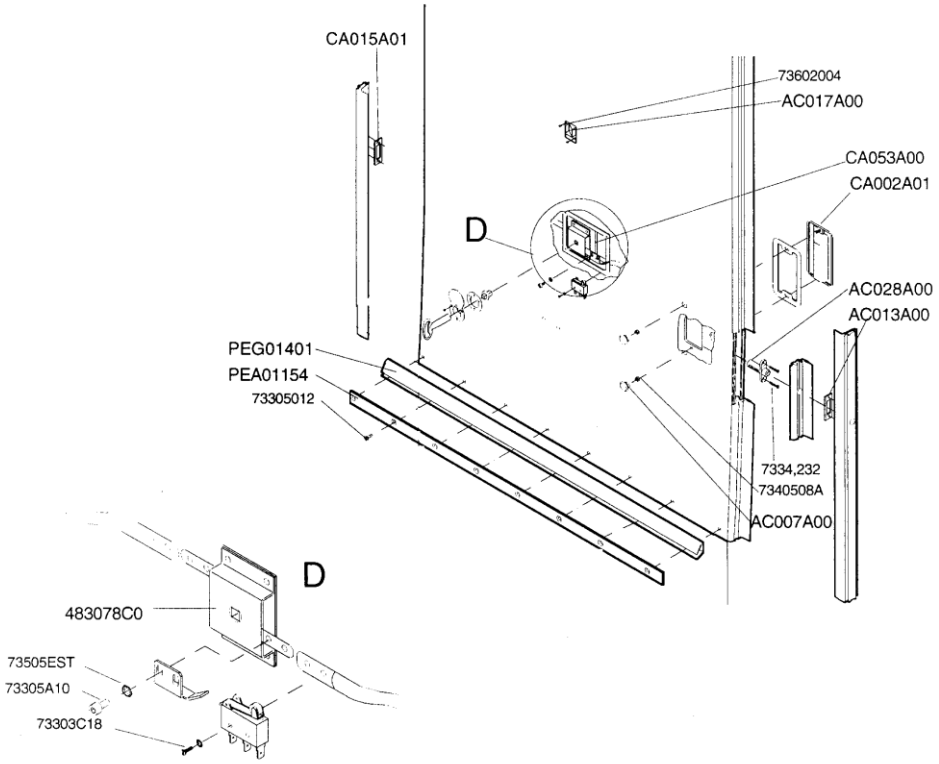

Figure 20: Mechanical locking of the service doors.

2 BEHAVIOUR OF THE PASSENGERS IN THE EVACUATION OF THE VEHICLE.

The hypotheses about the behaviour of the survivors during the evacuation of the vehicle are elaborated from the declarations of themselves, given the fact that the final state of the damaged coach vehicle provides little valid information in this field.

However, these statements should be analysed with caution, given that they are often contradictory. This is due to the strong state of stress experienced by passengers during the course of the accident, the speed with which different relevant events occur and, in this case, the darkness and the existence of black and dense smoke, which hinders visual perception . All this relativizes the space-time valuations of these passengers.

2.1 Declarations of the survivors concerning the evacuation of the vehicle.

The declarations of survivors of the accident related to the availability and existence of exits in the vehicle are shown in the following table (Table 3).

Then, the conclusions drawn from these statements are graphically represented, as well as the final state of the vehicle (Figure 21 and Figure 22).

Figure 21 shows the plant of the vehicle, indicating on it the location of the passengers in the moments preceding the collision.

In each seat, the central number refers to the age of the occupant of the same, while the one located in the upper left corner corresponds to the identification number of the passenger's declaration (Table 3:Table 3).

On the other hand, the colour of the seat indicates the severity of the occupant's injuries, according to the key:

- Green: Light or slight injuries.
- Yellow: Serious injuries.
- Red: Fatalities.

On this scheme it has also been represented the trajectories predictably followed by the passengers in their attempt to reach the exit.

Finally, the possible starting point of the fire is indicated, as well as the points of location of destroyed areas to get out of the vehicle (glass, side panels), represented by a star. An exception should be noted in the case of the red star positioned on the front windshield, corresponding to the breakage of this windshield by the driver, which was projected after the collision. The graph on

Figure 22 represents the external appearance of the exits used by the survivors during the evacuation.

Table 3: Declarations of the survivors regarding the exits used in the evacuation.

BAILEN ACCIDENT BETWEEN A COACH AND A TOURIST: DECLARATIONS OF SURVIVORS. EXITS.								
	Exit path	Exit time	Exit conditions	Exit status				Emergency Systems
				Front service door	Rear service door	rear window	Stairs	
1 María del C. Moya	Front service door	One of the firsts	Quiet, without stress	Is opened	It has a small opening, forced by people Some people come out here, until the exit is blocked by an obese fainting woman.			Do not see hammers. She does not know anything about emergency switches.
2 María del C. Torres	Front service door			Totally opened	It has a small opening, forced by people Then, forced by people, it opens up completely. Some people come out here, until it gets blocked by something unknown			Do not see hammers. She does not know anything about emergency switches.
3				Initially partially	It has a small	From inside, they break		Do not see hammers.

BAILEN ACCIDENT BETWEEN A COACH AND A TOURIST: DECLARATIONS OF SURVIVORS. EXITS.								
	Exit path	Exit time	Exit conditions	Exit status				Emergency Systems
				Front service door	Rear service door	rear window	Stairs	
Pedro León	Front service door			opened Afterwards is completely opened by kicks	opening, where some people come out. Then, he opens it completely but is hindered by Adela Ríos.	the rear windshield glass, launching a fire extinguisher.		He does not know anything about emergency switches.
4 Idelfonso García	Front service door				Half-opened and hindered by a faint person.	From inside, they break the rear windshield glass.		
5 Francisca Moya	Front service door		No initial burdens		Half-opened and hindered by fainting person: Adela Ríos. Together with her husband, they bring out Adela, and revive her.			
6 Pilar	Front service door with her son.		Screams and fear occur					Does not see any hammer

BAILEN ACCIDENT BETWEEN A COACH AND A TOURIST: DECLARATIONS OF SURVIVORS. EXITS.								
	Exit path	Exit time	Exit conditions	Exit status				Emergency Systems
				Front service door	Rear service door	rear window	Stairs	
Rodríguez								
7 Andrés Jimenez	Rear door		Screams and fear occur		They leave by small hole forced by people			Do not see hammers. She does not know anything about emergency switches.
8 Felisa Rodriguez	Front service door, crawling.							Do not see hammers. She does not know anything about emergency switches.
9 Luis Jiménez	Front service door		No initial burdens	A gap is opened initially by impact deformation. Then, the door opens by kicks.	* Ajar and hindered by fainting person: Adela Ríos. * Also falls on exit 'guardrail located in front of' WC	From inside, they break the rear windshield glass, launching a fire extinguisher.	A child goes through a hole in the luggage compartment.	Do not see hammers. She does not know anything about emergency switches.
10 Benito Orellana	Rear door pulled out by another person							

BAILEN ACCIDENT BETWEEN A COACH AND A TOURIST: DECLARATIONS OF SURVIVORS. EXITS.								
	Exit path	Exit time	Exit conditions	Exit status				Emergency Systems
				Front service door	Rear service door	rear window	Stairs	
11 Francisco Sáez	Rear door				It remains open, after being forced. Falling board on the ladder Obese woman faints, and blocks the exit "			Does not see any hammer
12 José Pérez	Front service door				Half opened			Do not see hammers. She does not know anything about emergency switches.
13 Damaris Barriga	Rear door				Fully opened			
14 Raquel Barriga	Front service door			Fully opened				
15 Sheila Arance	Rear door				Exits through a hole in the upper part			

BAILEN ACCIDENT BETWEEN A COACH AND A TOURIST: DECLARATIONS OF SURVIVORS. EXITS.								
	Exit path	Exit time	Exit conditions	Exit status				Emergency Systems
				Front service door	Rear service door	rear window	Stairs	
16 Manuel Vela Ortiz	Front service door			Totally open It has been opened by the driver's son (with control)	Blocked			
17 Consuelo Ramos	Through a hole in the stairs (in front of the WC)				When it comes out, rear door does not open		Exits with her son.	
18 Samuel Lara	Rear window					Breaks glass with extinguisher at his feet		Do not see hammers. She does not know anything about emergency switches.

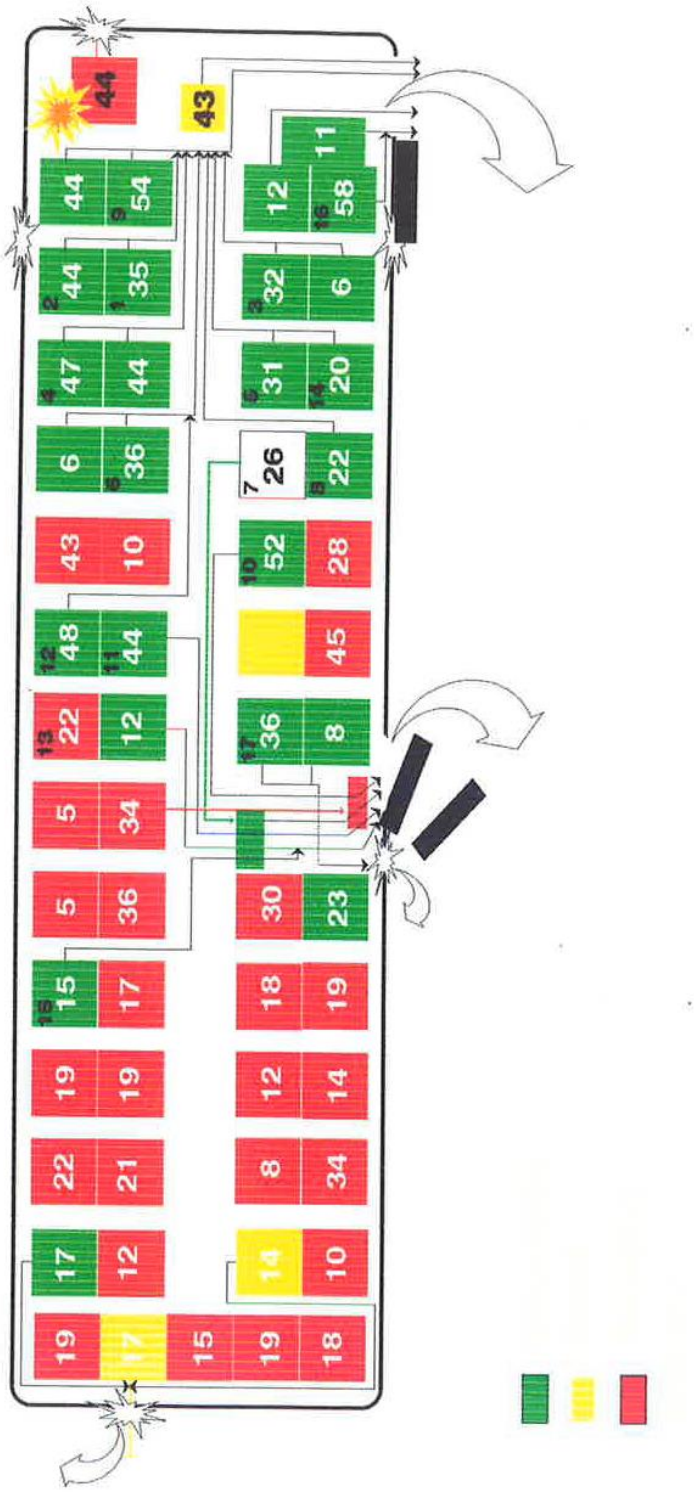

Figure 21: Exits used in the evacuation of the damaged vehicle. Plan view.

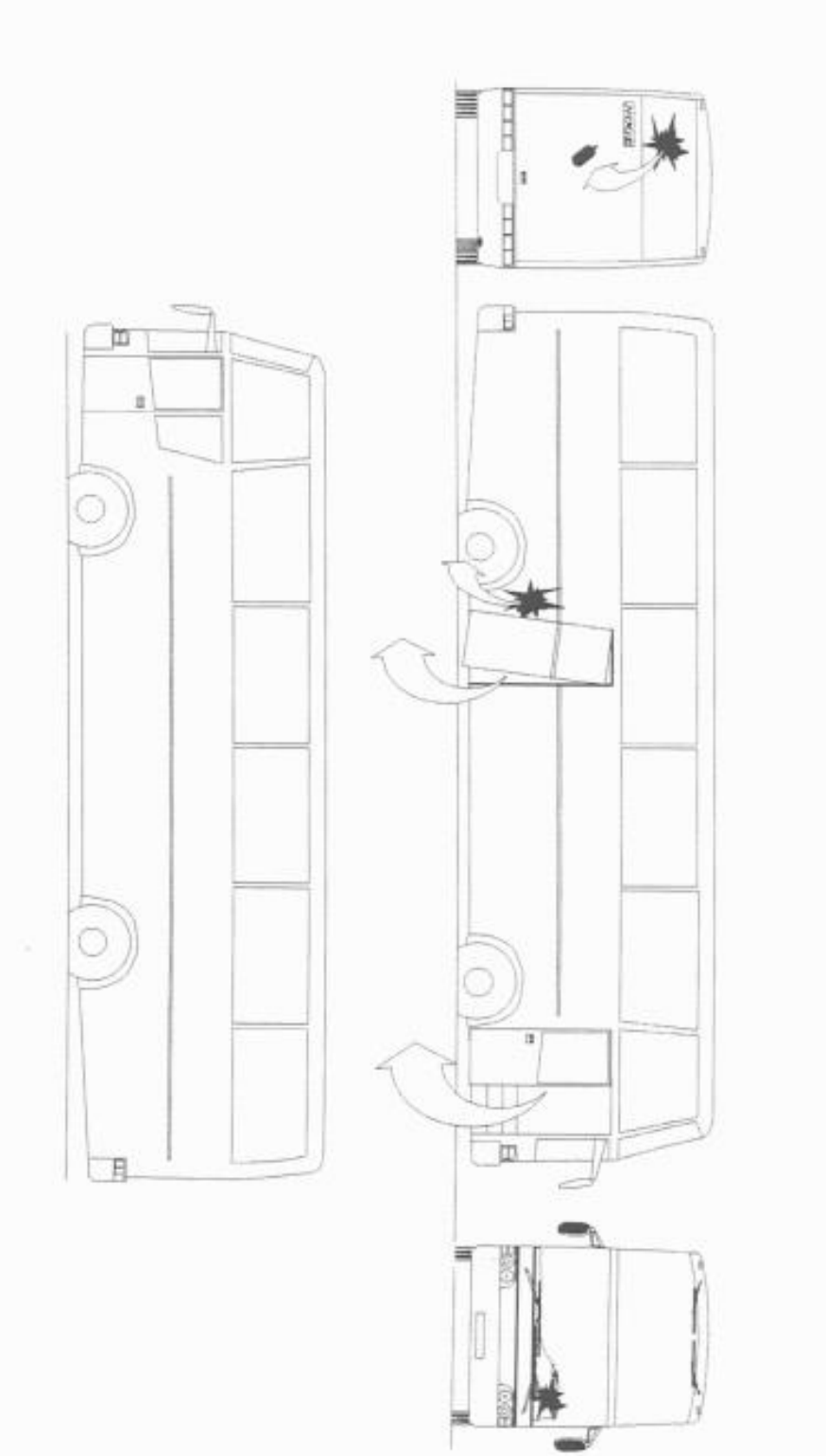

Figure 22: Exits used in the evacuation of the damaged vehicle. Elevation view.

2.2 Conclusions drawn from the statements of the survivors about the exits used for the evacuation of the vehicle.

2.2.1 Emergency windows.

The emergency windows have not been practically used during the evacuation. Only in the final instants, the back window is used.

The breaking of the crystals of these exits is easy by means of the hammers arranged inside the interior for this purpose. However, in this sinister these hammers have not been used, due to the impossibility of locating them, which can be motivated by various causes:

- Unawareness of the mission of the hammers. This entails that the passenger does not pay attention to the location of this tool when traveling in the vehicle.
- None of these hammers present on the vehicle. This point cannot be corroborated, due to the final state of destruction of the vehicle.
- Inaccessibility of the same. The place of placement of the hammers does not have emergency lighting. This causes that they cannot be easily located in the existing atmosphere inside the cabin where:
    - The interior lighting of the passenger compartment after the collision has been destroyed.
    - There is no external lighting.
    - There is an internal atmosphere of very low visibility, due to the smoke generated by the combustion of the interior materials.

In view of the lack of availability of the hammers, it is necessary to generate strong concentrations of stress in the glass. Only in the final moments of the accident has one of the extinguishers been used to break the rear windshield.

2.2.2 Service doors.

The unlocking of the service doors of the vehicle is carried out by the release of pressure in the pneumatic circuit. This release can be voluntary or involuntary, through:

- Control command in driver's station.
- Emergency controls on doors.
- Losses due to deficiencies in the circuit.

In the damaged vehicle, despite the strong impact, there is no immediate unlocking of the service doors due to leaks in the pneumatic door control system. This forces the need to act on the controls located in each of them, since the control command located in the driver's position has rendered useless after the collision.

The front door was opened practically in its entirety. Thus, on the one hand, the deformation of the frame of the same occurred after the impact, which left a gap between that frame and the door through which the evacuation began. Along with this, it was able to produce the unlocking by the use of the emergency switch, which allowed passengers to easily open that door by pushing in the first moments after the stop the vehicle. This fact made possible the use of this exit, until it was blocked by the flames.

In the rear door the emergency controls were not activated, neither from inside nor from the outside, so it was cancelled. The passengers tried the opening by pushing on it, achieving a small hole through which some survivors left. However, this situation worsened when one of the passengers, of large volume, collapsed on the left side in the rear exit, which was rendered useless access to the outside.

Finally, this rear exit was opened in its entirety, according to the testimony of some passengers. This could produce to affect the flames to the pneumatic circuit and to motivate the leak of air of the same. However, this opening was made too late, when the passengers who were still inside the vehicle had been affected by the smoke, and in some cases by the flames.

This mode of behaviour of the passengers of the vehicle confirms the fact that the ignorance of the emergency systems existing in a vehicle can cause serious consequences, such as those that occurred in this accident.

2.2.3 Other departures

Noticeable in this regard are the statements made by some of the survivors, in which it is stated that the passengers manage to open an opening from the inside on the sidewall of the vehicle, located next to the rear service door on the side opposite the WC. This opening allows the exit of two people.

The possible gap is shown in Figure 21 and Figure 22. However, it seems unlikely the exit of passengers by it. It is possible that, in the low visibility conditions described, this lateral gap was confused with the exit hole left by the rear door.

3 EVACUATION TESTS.

3.1 Objectives.

In order to determine the predictable behaviour of the passengers of a coach in case it is necessary to quickly evacuate the vehicle after a traffic accident, a series of evacuation tests have been conducted. This tests have served to establish a minimum threshold value for the time necessary to carry out the complete eviction of the vehicle.

Given that there is no current legislation related to the evacuation tests of large capacity vehicles, the regulations in force in civil aviation have been used to establish criteria and a testing procedure (Standard 14, parts 60 to 139 (1-1-88 Edition) of the Federal Aviation Administration of the USA). From this norm, those sections of possible application to the evacuation of a large vehicle for the transport of passengers have been extracted, highlighting the following aspects:

1. A demonstration of evacuation methods for airplanes with a capacity of more than 44 passengers is mandatory before starting a trip. The coach in question has a capacity of 55 passengers and the convenience of transmitting this information to passengers of a coach is highlighted.
2. During the demonstration of evacuation methods, it should be explained:
    - Introduction to the type and model of aircraft.
    - Number and location of emergency exits.
    - Number and location of evacuation systems or procedures or type of opening mechanisms in doors available for evacuation.
3. It must be possible to evacuate completely, passengers plus crew, in a maximum time of 90 seconds.
4. To check the previous point, a simulation must be carried out under the following conditions:
    - The simulation has to be done at night or with the darkness of the simulated night.
    - The airplane has to be in normal position and with the landing gear extended.
    - Only ramps and emergency material should be used for passengers to reach the ground.
    - It should only be illuminated with emergency lights.
    - All emergency equipment must be installed.
    - All doors and windows or curtains must be in the take-off configuration.
    - Each member of the crew must remain in their assigned seat for the take-off and remain there until they receive the order to start the simulation. Each crewmember must be:
        - Part of an airline crew.

        - A person who knows the operation of doors and emergency systems.
    - - The set of passengers must be representative of a sample such as the one described below, in a normal state of health:
        - At least 30% of women.
        - At least 5% over 60 years, with an adequate proportion of women.
        - At least 5%, but not more than 10%, must be children under 12 years of age.
        - Three dolls of real human size, not counted as passengers, should be used to simulate babies of two years old or less.
    - They cannot be part of the passengers:
        - Crew members.
        - Mechanics or aircraft maintenance personnel.
        - Operators
    - Passengers should not be assigned to any specific seat.
    - Passengers must have a seat belt fastened.
    - Before starting the simulation, approximately half of the average hand luggage, blankets, pillows, etc., should be distributed in the corridors and emergency exits to create minor obstacles.
    - Each member of the crew must be seated in the assigned seat for the take-off and remain there until the moment of receiving the signal to start the simulation.
    - No prior explanation should be given to the passengers or crew of the exits that will be used for the simulation.
    - No participant must have been part of a simulation in the previous six months.
    - Passengers should be advised to follow the orders of the crew, but not instruct them in the procedures.
    - All safety equipment must be available.
    - On each side, no more than 50% of the available emergency exits should be used. Those that are not used must be indicated by a red light, cover, etc., simulating the existence of fire.
    - All evacuees must leave the plane with the means provided by their security systems.
    - The simulation ends when the last evacuee reaches the ground.

3.2 Results

Taking these regulations as a reference, evacuation tests have been carried out, which are detailed below, with the collaboration of the transport company ALSA,

which made a 48-seat bus available to the INSIA. The procedure that was followed was as follows:

1. Although it is recommended that the simulation be done at night or with the darkness of the simulated night, given the impossibility of performing the simulation under these conditions, it was done during the day.
2. All emergency equipment was installed.
3. The set of passengers was representative of a sample such as the one described below, in a normal state of health:
    - At least 30% of women.
    - At least 5% over 60 years, with an adequate proportion of women.
    - At least 5%, but not more than 10%, must be children under 12 years of age.

The participants were those listed below, with a total of 48 passengers (places available on the coach used to carry out the trial):

- 17 Women (35.4%):
    - Maite .....25 yo
    - Iciar .....27 yo
    - Beatriz .....27 yo
    - Victoria .....31 yo
    - Begoña.....24 yo
    - Flor .....25 yo
    - Ana Pilar.....44 yo
    - Eloisa .....28 yo
    - María Jesús.....30 yo
    - Sonsoles .....26 yo
    - Rosa.....30 yo
    - Pilar .....33 yo
    - Silvia.....20 yo
    - Ana.....20 yo

    * 3 over 60 yo (6.25%).
        - Anselmo .....69 yo
        - Alberto.....69 yo
        - Julian.....63 yo

    * 5 children under 12 yo (10.41%).
        - Cristina .....6 yo
        - Noemi.....8 yo
        - Tania .....8 yo
        - Jesús.....4 yo
        - Sergio.....2 yo

* 23 men (47,9 %).

Rufino.....25 yo
Borja.....23 yo
Fernando.....24 yo
Antonio.....25 yo
Miguel.....38 yo
Fernando.....24 yo
Rafael.....25 yo
Jesús.....26 yo
Manuel.....24 yo
Juan Carlos.....25 yo
Adrian.....29 yo
Paco.....31 yo
Manolo.....42 yo
Pedro.....28 yo
Sergio.....53 yo
Isidro.....28 yo
Javier.....24 yo
Angel.....26 yo
Julio.....23 yo
Luis.....24 yo
Javier.....29 yo
Juan Luis.....19 yo
Adolfo.....41 yo
Antonio.....48 yo
José.....19 yo

Average age of the sample: 28.5 years

Typical deviation: 14.15

4. The passengers were not assigned to any specific seat.
5. Passengers must have a seatbelt fastened, if the seat has a belt.
6. The driver was sitting in the assigned seat and remains there until the signal to start the simulation is received.
7. No prior explanation was given to the passengers or the driver of the exits that were used for the simulation.
8. Since most of the emergency exits are windows in a bus and cannot be used in the simulation, only one or both service exits were used.
9. All the evacuees had to leave the bus with the means provided by their security systems (the doors remained closed and had to be opened by the passengers using the emergency controls).
10. The simulation ends when the last evacuee reaches the ground.

The results obtained were the following:

First simulation: No prior instruction was given. The two service doors of the coach were used.

Time spent on evacuation: **43 seconds**

Second simulation: Passengers in the rear area were asked to use the central door and those in the front using the front of the coach. The two service doors of the coach were used.

Time spent on evacuation: **35 seconds**

Third simulation: No prior instruction was given. The front door was blocked without warning.

Time spent on evacuation: **57 seconds**

Fourth simulation: No prior instruction was given. The back door was blocked without warning.

Time spent on evacuation: **66 seconds**

Fifth simulation: No prior instruction was given. The two service doors of the coach were used. The seats moved towards the corridor, narrowing it.

Time spent on evacuation: **34 seconds**

Sixth simulation: No prior instruction was given. Only the front door was used. The seats moved towards the corridor, narrowing it.

Time spent in evacuation: **60 seconds**

The shorter times measured in the fifth and sixth simulations compared to the second and fourth simulations must be attributed to the fact that all the tests are carried out with the same group, and this generates a certain training, which decreases the times even in the case of narrower aisle.

After the analysis of the evacuation simulations carried out, the following is concluded:

1. Practically in all cases the evacuation is carried out in a maximum of one minute, even in the test with a locked door.
2. Having an impact on the improvement of lighting and information on vehicle evacuation systems, it is possible to complete this evacuation in a time not exceeding 35 seconds.

3. Windows have not been used as exit for security reasons of the group members who have participated in the tests. Given the reduced evacuation times measured, in most cases it may be more feasible to quickly evacuate a coach vehicle through the doors than to try to break windows.
   However, in the accident that is studied and considering the influence of smoke, the breaking of windows plays a key role in the evacuation of the vehicle.

4. It would be convenient to carry out tests in conditions of low or very low visibility. However, it can be assumed, in light of the results obtained, that with adequate information about the existing exits and their use, as well as the use of indicator lights in cases of blackout, the evacuation time should not exceed the specified 90 seconds in the air regulations.

4 TESTS OF BREAKAGE OF THE WINDOWS OF THE COACH VEHICLE.

The tests were carried out in the facilities of the HISPANO CARROCERA S.A. bodybuilder, in Zaragoza, on July 31, 1996.

4.1 Objectives.

The behaviour during the evacuation of a coach is strongly conditioned by the use of the exits. The objective of these tests is to evaluate the possibility of using the existing windows in the vehicle.

The development of section 1 (Description of the exits available in the vehicle.) shows the types of windows present in the injured bus. From the point of view of the evacuation, the front windshield is difficult to use (laminated glass). The rest of the windows are ready to be broken in case of emergency.

Because of this, the present group of tests focuses on the breaking behaviour of the side windows and the rear windshield.

4.2 Procedure.

The window breakage tests must reproduce the actual installation conditions in the damaged vehicle. Therefore, these tests are developed according to the following specifications:

1. All the windows of the vehicle do not have the same configuration, so the tests must contain samples of all types present. Thus, in the sinister coach appear two different configurations:
    a) Rear windshield: a single sheet, 5 mm thick, of tempered glass.
    b) Side windows: double sheet, 5 mm thick each, with intermediate air chamber 8 mm thick. The glass is also tempered.
2. The way of placing the glass on the frame must be identical to that used on the injured coach. These glasses are glued to the frame, a remarkable fact given that the fixing material used absorbs part of the impact energy. This fixation is shown in the following photograph (Figure 23).
3. The tests are not carried out on the coach vehicle, but the glass with its corresponding frame are fixed to a structure located in the open air, in order to avoid possible damages or injuries during the application of the impact. This structure is presented in the following photograph (Figure 24).

Figure 23: Adhesive fixing glass windows to the frame. Glass breaking tests.

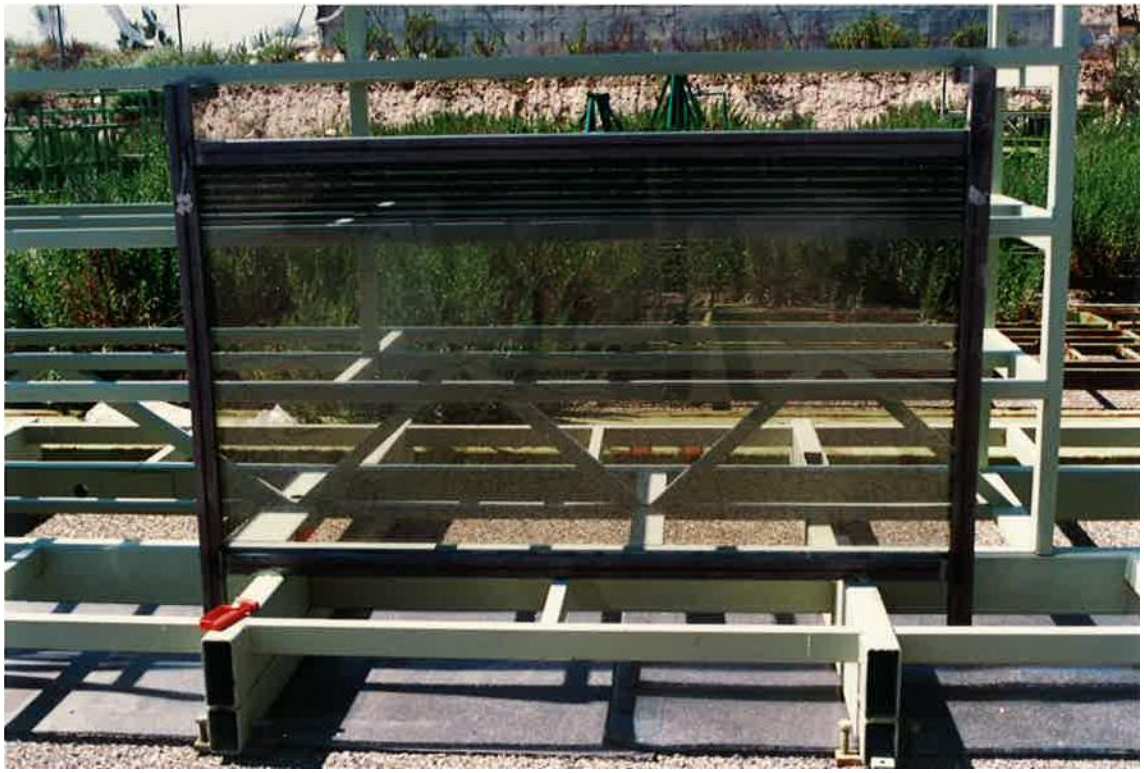

Figure 24: Frame structure of windows. Glass breaking tests.

4. The elements used for the destruction of the glass must be objects usually existing in the interior passenger compartment of the vehicle. Considering this specification, the following objects have been chosen:
    a) Hand.
    b) 2 types of shoes, with different configuration of sole: a gentleman's shoe, with flat rubber sole; and a lady's shoe, with a rubber sole, and a softly sharpened heel.
    c) An empty glass bottle, with a capacity of 33 cl.
    d) Common keys for opening doors.
    e) Fire extinguisher full.
    f) Hammer breakage of emergency windows (such as those usually found in coach vehicles).
5. For the application of these objects on the windows a person of male sex, of 27 years of age, and of medium build is chosen.

4.3 Results of the trial.

The breakage tests carried out provide the following results:

4.3.1 Objects that do not destroy the windows.

- The hand, applied with a force that does not damage the subject, is not capable of destroying the glass.
- The shoes do not break windows, whether they are applied through the foot or through the hand.

  In the case of application with the foot, it has literally jumped over the moon, applying the maximum possible effort on the part of the user, which is not possible in the small space existing inside a real vehicle.

- The keys do not destroy the glass, because in spite of its sharp end (in some occasions), they have little weight, and are difficult to be fastened by the user in such a way that they constitute an aggressive element.

4.3.2 Objects that destroy the windows.

- The emergency hammer is constituted by a rigid plastic body. In its upper part it is provided with a metallic cylinder, which has a sharp-tipped end, and the opposite end rounded and covered with the same constituent plastic of the body.

This hammer destroys the glass with its sharp part without difficulties, not requiring the application of a great effort on the part of the user. The impact causes the general cracking of the glass.

At this time, it is important to distinguish between the two types of windows used:

  - The simple window falls easily by thrust once cracked.
  - In the case of the double moon, and supposedly cracked only the inner sheet, it does not fall by pushing since the opposite sheet does not allow its deformation by pressure. It is necessary to break both sheets to create a space that allows the passage of the occupants.

- At the same time, the opposite end of said hammer has been used to hit the window. This end has a rounded shape and is covered with rigid plastic. The result of this test has been the destruction of the impact element (said hammer has been broken in its central area), causing no effect on the glass
- The glass bottle is supported by the upper neck, using the lower seat of the same as an impact element. This end easily provokes the breaking of the moon, as seen in the photograph shown below (Figure 25).
- Finally, the fire extinguisher, given its high weight, destroys the glass, generating an appreciable gap by penetration. This essay is presented in the following photograph (Figure 26).

Figure 25: Simple moon break with bottle.

Figure 26: Simple moon break with fire extinguisher.

After the analysis of the results obtained in the glass breakage tests, the ideas shown in the following table are summarized (Table 4), in which the usefulness of different objects for the breakage of the glass of the emergency windows is presented.

Table 4: Usefulness of different objects present in the coach compartment, for the breakage of the glass of the emergency windows.

OBJECT	EFFECTIVENESS
Emergency hammer (metal side)	Effective
Emergency hammer (non-metal side)	Ineffective
Empty glass bottle	Effective
Fire extinguisher	Effective
Hand	Ineffective
Shoe (Rubber sole)	Ineffective
Keys (Building door)	Ineffective

5 CONCLUSIONS

The analysis of the study developed in this section allows reaching the following conclusions:

CONCLUSION 1.- The number and disposition of the exits specified in Regulation 36.03 allows the evacuation of the coach vehicle in a maximum time of less than 70 seconds, without considering the use of emergency windows.

This time has been estimated without providing the occupants with prior information about the exits present in the coach vehicle, and in conditions of adequate visibility.

CONCLUSION 2.- The existence at the disposal of the occupant of the information vehicle about the emergency systems installed therein can significantly condition their behaviour during the evacuation, as well as the time invested in it.

CONCLUSION 3.- The ease of locating and using existing emergency devices in coaches greatly improves the evacuation process of the vehicle in the event of an accident.

CONCLUSION 4.- The provision of these emergency devices with autonomous lighting systems determines their location in the low lighting conditions that may arise after an accident.