SDWEE-02-05
22 January 2010

# NEW REQUIREMENTS TO EMERGENCY EXITS AND THEIR USE ON BUSES

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Warsaw meeting: January, 2009

# EMERGENCY EXITS ON BUSES

Emergency exit (EE)can be:

- Service door
- Emergency door
- Emergency window (side and rear)
- Escape hatch
- Driver's cab door

Requirements in Reg.107/Rev.1 (Annex 3. para 7.6; Annex7 para 1.2 and Annex 9. para. 7.6.1 – 7.6.2)

- Number of exits
- Their location, arrangement
- Minimum dimensions and access to them
- Technical (operational) requirement

# EMERGENCY EXITS ON BUSES

In R.107/Rev.1 the main principles are based on:

- Proportionality to the passenger capacity of the bus
- Separated passenger and driver's compartment separately treated
- Each of the two sides, as well as the front and rear part of the bus shall have substantially the same number of exits

It is not stated, but assumed in the regulation:

- The bus is standing on its wheels
- All EE-s are equivalent on a bus
- All EE-s are equivalent in all emergency situations

# EMERGENCY EXITS ON BUSES

The EE-s can be used only, if the bodywork is not strongly damaged

General collapse of the superstructure

In these cases no sense of emergency exits

# EMERGENCY EXITS ON BUSES


Local large scale deformation of the bodywork

# DIFFERENT EMERGENCY SITUATIONS

## Emergency situations to be considered:

- **Rollover** accident considering all possible final bus position
- **Frontal collision** considering total or partial impacts
- **Side impact** on both sides considering heavy impacting partner
- **Rear impact** with heavy impacting partner
- **Fire** in the bus considering different fire locations
- **Bus is in shallow water** (lake, river) but not fully sunk
- **Combined** accidents
- **Special** situations

# DIFFERENT EMERGENCY SITUATIONS

**Rollover:**
- most complex accident
- after the accident the bus could be in different positions
- it covers all other accident situations, when the bus is standing on its wheels
- injured passengers on board
- passengers in unusual positions
- panic

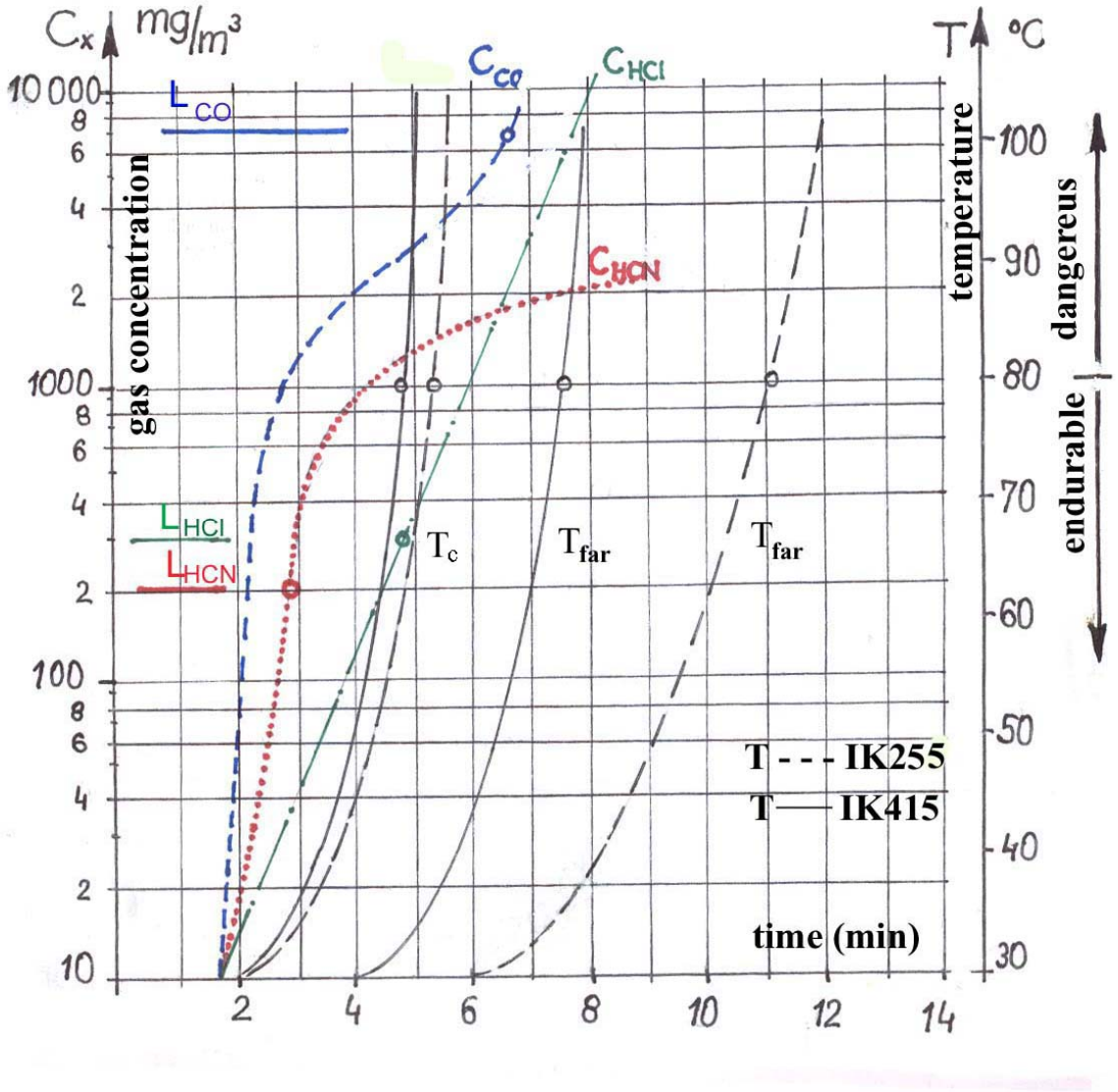
**Fire:**
- time limit, in which the bus must be evacuated (smoke, poisoning gases, high temperature)
- location of the fire can rule out the use of certain EE-s

# DIFFERENT EMERGENCY SITUATIONS

Fire tests with three buses (type: IK255 and IK415)
Smoke, poisoning gases and temperature

Fire started in the box of the heating device

# DIFFERENT EMERGENCY SITUATIONS




Available time
for evacuation:

200 – 300 sec

# SOME EXAMPLES

Emergency side windows in DD coaches

Frontal collision
Upper deck, side windows, usability: very weak
Lower deck, side windows, usability: very good

# SOME EXAMPLES

Windscreen as emergency exit (cutting the laminated glass)

The bus is lying on its side (door side)

The usability of the windscreen: good or very good

The service door and the emergency windows on the right side are unusable

# SOME EXAMPLES

## Standing on the roof

small bus

large bus

| | | |
|---|---|---|
| weak | Windscreen | very good |
| very good | Rear door | - |
| acceptable | Side windows | very good |
| - | Rear window | very good |
| unusable | Escape hatches | unusable |

# SOME EXAMPLES

DD coach lying on its side

**Upper deck:** escape hatches, usability: good

**Upper and lower deck:** emergency windows on left side: unusable

emergency windows on right side: usability is very weak

# SOME EXAMPLES

Standard 12 m long coach laying on its left side

Rear window (broken) usability is good or very good

Escape hatches usability is good (or unusable, see the tree)

Side emergency windows on the left: unusable

Side emergency windows on the right: usability is very weak

# USABILITY OF EMERGENCY EXITS

## Four milestones about usability:

- The usability of different EE-s in one accident situation is different (compare service door with escape hatch in rear collision)
- The usability of one EE in different accident situation could be different. (compare escape hatch in „lying on side” or „standing on wheels”)
- The usability of the same type of EE-s could be different in different bus categories (compare emergency side window in low floor bus or in HD coach)
- The usability of the same type of EE-s could be different in the same vehicle (compare side windows in the lower or upper deck of DD buses, or the two sides of a lying bus)

# USABILITY OF EMERGENCY EXITS

Classification of usability:

very good, good, acceptable, weak, very weak, unusable

Specification of usability:

- opening of the exit
- climbing up to the exit, when use it
- jumping dawn from the exit, when use it
- continuous use (considering children, elderly people and injured persons, too.)

# USABILITY OF EMERGENCY EXITS

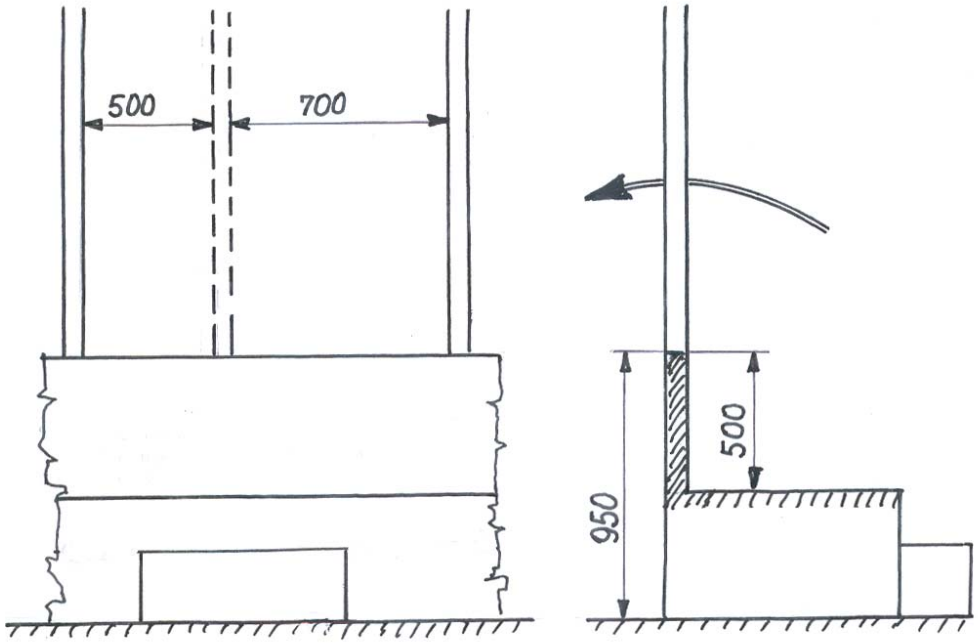
## Possible specification

| Usability<br>Technical aspect | Very good | Good | Acceptable | Weak | Very weak | Unusable |
|---|---|---|---|---|---|---|
| Opening (1) | done by the driver | simple, easy, small effort by passenger | simple, small knowledge and effort by passenger | considerable effort and skill is needed by passenger | outside help is needed | In the given situation it is put out of action |
| Climbing up to the exit when use it | no need | no need | less than [1 m ] | more than [1 m ] | more than [1,5 m ] | |
| Jumping down from the exit when use it | no need | less than [1 m ] | less than [1,8m ] | less than [1,8 m ] | more than [1,8 m ] | |
| Possibility of continues use | possible, no obstacles, difficulties | possible with small help | Possible with inside and outside help (not skilled) | possible with inside and outside help (skilled) | not possible | |

(1) opening includes: to find the exit, to approach it, to understand its operation and to open it

# EVACUATION TESTS

## UK test, Cranfield




Side window simulation

The situation is not realistic

Sample: 100 elderly people

(58 – 73 – 89)

3 kind of exit width

55% performed the test

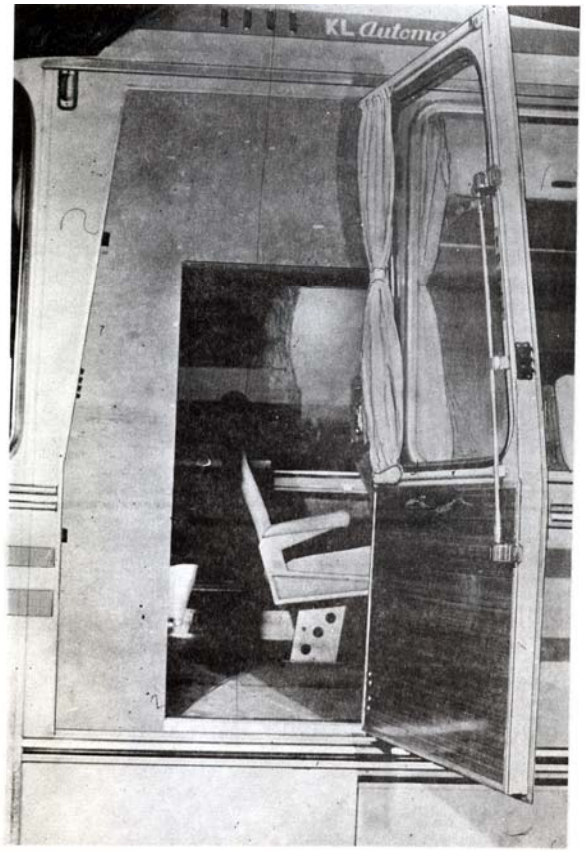
45% refused to do it

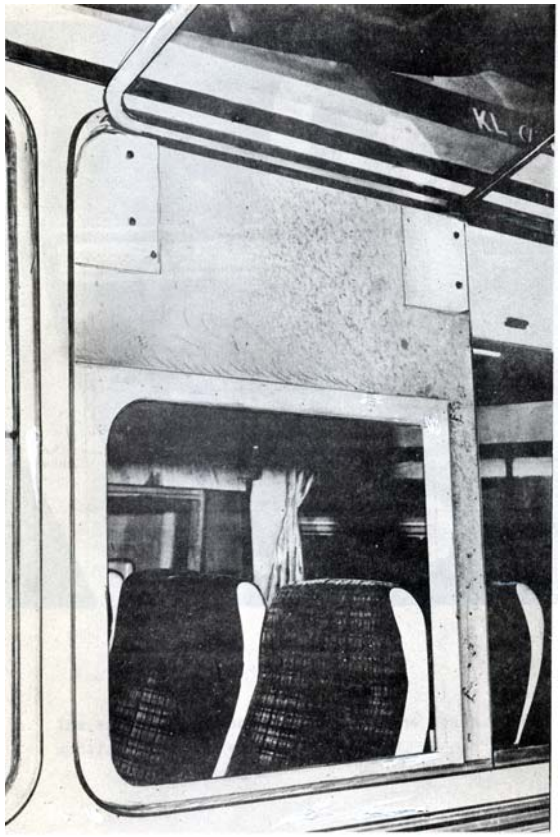
Average time to perform the test:

500 mm width:  10 s/person

1200 mm width:  7 s/person

# EVACUATION TESTS



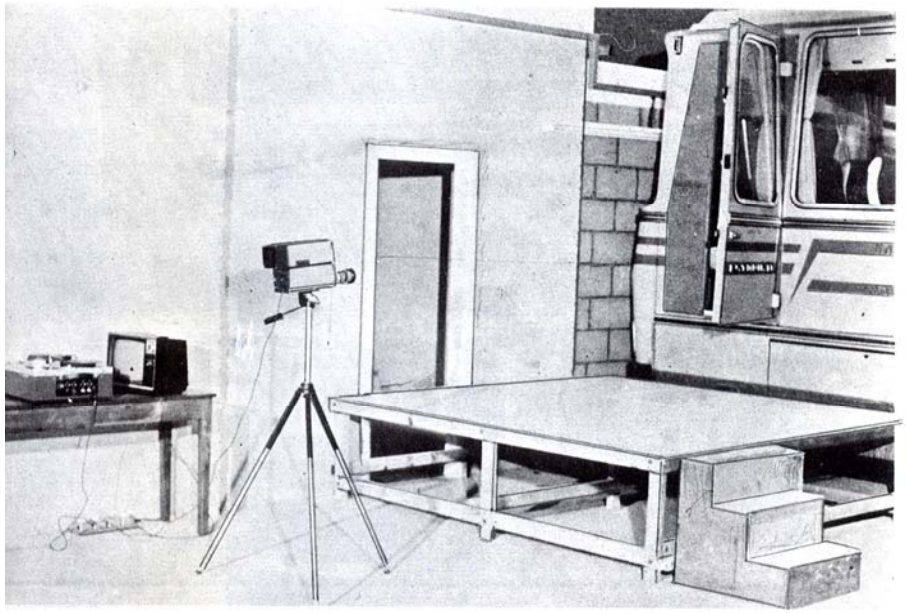


University of Technology, Loughborough (UK)

Evacuation tests with emergency door and side window

| | | |
|---|---|---|
| Three passenger groups: | Gr. 1 | 7-15 years |
| | Gr.2 | 20-45 years |
| | Gr.3 | 60-75 years |

# EVACUATION TESTS



Test with outside podiums

48 persons in every passenger group (50% male/female)

The complete evacuation time was measured (empty bus)

# EVACUATION TESTS

Test without outside podium

Different passenger motions with or without podium

# EVACUATION TESTS

## Measured evacuation times

| Way of evacuation | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| Emergency door with podium | 120 sec | 150 sec | 240 sec |
| Emergency door without podium | 210 sec | 210 sec | * |
| Emergency window with podium | 270 sec | 330 sec | 600 sec |
| Emergency window without podium | -** | 540 sec | ** |

* not all the passengers could make the test
** Group 1 and 3 could not perform this test

Some interesting ratios:

| | |
|---|---|
| Male/female | 1: (1,2 – 1,5) |
| 12 faster/12 slower passengers | 1: (1,2 -1,6) |
| Emergency door/side window | 1: (2,2 – 3,5) |

# EVACUATION TESTS

German test series:

- real Class II. and Class III. vehicles
- vehicles standing on wheels
- two groups of passengers: children (8-10 y.) and adults
- service doors, side windows and their combination
- side window tests with outside podium
- complete evacuation times were measured (empty bus)

# EVACUATION TESTS

## Measured evacuation times

| Way of evacuation | Class II | | Class III | |
|---|---|---|---|---|
| | children | adults | children | adults |
| 2 service doors (SD) (1) | 30 sec | 30 sec | 40 sec | 30 sec |
| 2 emergency windows (SW) (3) | - | 52 sec | - | 52 sec (2) |
| 2 SD + 2 SW | - | 15 esc | - | 24 sec (4) |

(1) 2/3 of the occupants used the rear service door
(2) Half of the group left the vehicle trough a window
(3) Braking the window and cleaning an exit hole took 15 sec
(4) 2/3 of the occupants used the doors

Two interesting statements in the German document:

- most dangerous accident situation: the bus is burning while lying on its side
- at least two exit systems (instead of one) is needed with increased capacity: when the bus is standing on its wheels, or lying on its side

# EVACUATION TESTS

## Hungarian tests (AUTOKUT)

- Class III coach with 45 passengers
- Two groups of passengers: firemen (20-40 y); adults (25-45 y)
- Service door, emergency door, side window was tested
- Complete evacuation times were measured (empty bus)

# EVACUATION TESTS

## Measured evacuation times

| Way of evacuation | Passenger group | Number of tests | Evacuation time (s) |
|---|---|---|---|
| Front service door | firemen | 2 | 25-28 |
| Front service door | adults | 2 | 37-40 |
| Rear service door | adults | 1 | 40 |
| Two service doors | adults | 1 | 20 |
| Rear emergency door | adults | 1 | 54 |
| Side emergency windows | firemen | 1 | 10 |

# EVACUATION TESTS

Breaking the side window (30 years woman)

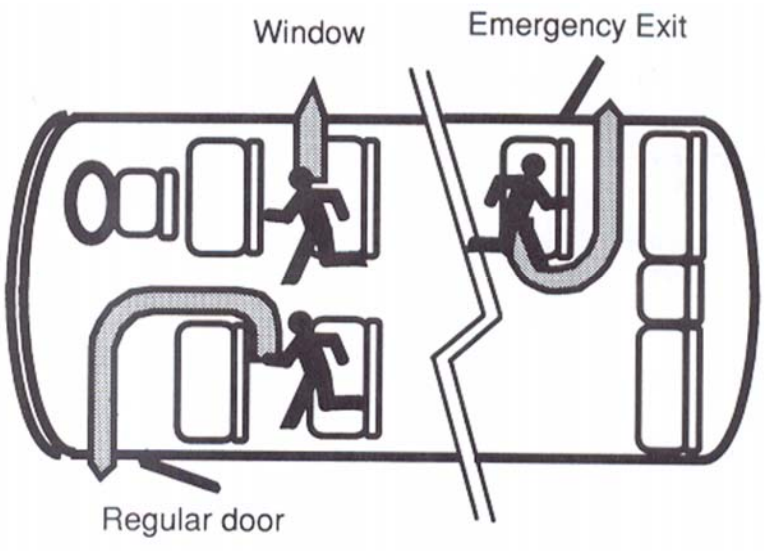
- finding and getting the hammer, cracking the glass 15 sec
- creating a „free exit” with appropriate size, additional 25 sec
- leaving the bus with strong outside help, additional 50 sec

$\sum$ 90 sec

The woman was afraid of climbing up and jumping through the window (sharp, pointed glass fragments on the waistrail)

# EVACUATION TESTS

## Test in Japan (JAMA)




- HD coach
- service door, emergency door, side window (sliding type) was tested
- outside podiums were used in the last two cases
- three passenger groups: children (8-12 y; adults (20-22 y); elderly people (66-73 y)
- three tests were made with every person
- measured evacuation time for individuals from starting the process (standing up from the seat) to the end (leaving the bus)

# EVACUATION TESTS

## Some results:

- evacuation time trough service door: 7 sec/person for Gr.1 and 2
  10 sec/person for Gr.3
- through emergency door or side window: 10 sec/person, no considerable difference between groups and exits
- ¾ of the evacuation time was needed to find and get EE, to understand its operation and open it
- At the first trial no one of Gr.1 and only half of Gr.3 could perform the test with emergency door. They could not open it.

# EVALUATION OF EMERGENCY EXITS

## Assumptions:

- no considerable structural damage
- the „four milestones” are considered
- the classification” and „specifications” discussed above are considered as first approximation
- special situations (bus in water, bus is standing close to a wall), are not considered yet
- certain, but not well defined cooperation is assumed among the passengers when evacuating the bus
- certain, but not well defined outside help is assumed (given by the driver or passengers being already outside) but not organized, trained, skilled help (e.g. fire-brigade)

# EVALUATION OF EMERGENCY EXITS

## The bus is standing on its wheels (in rollover after 1 complete rotation)

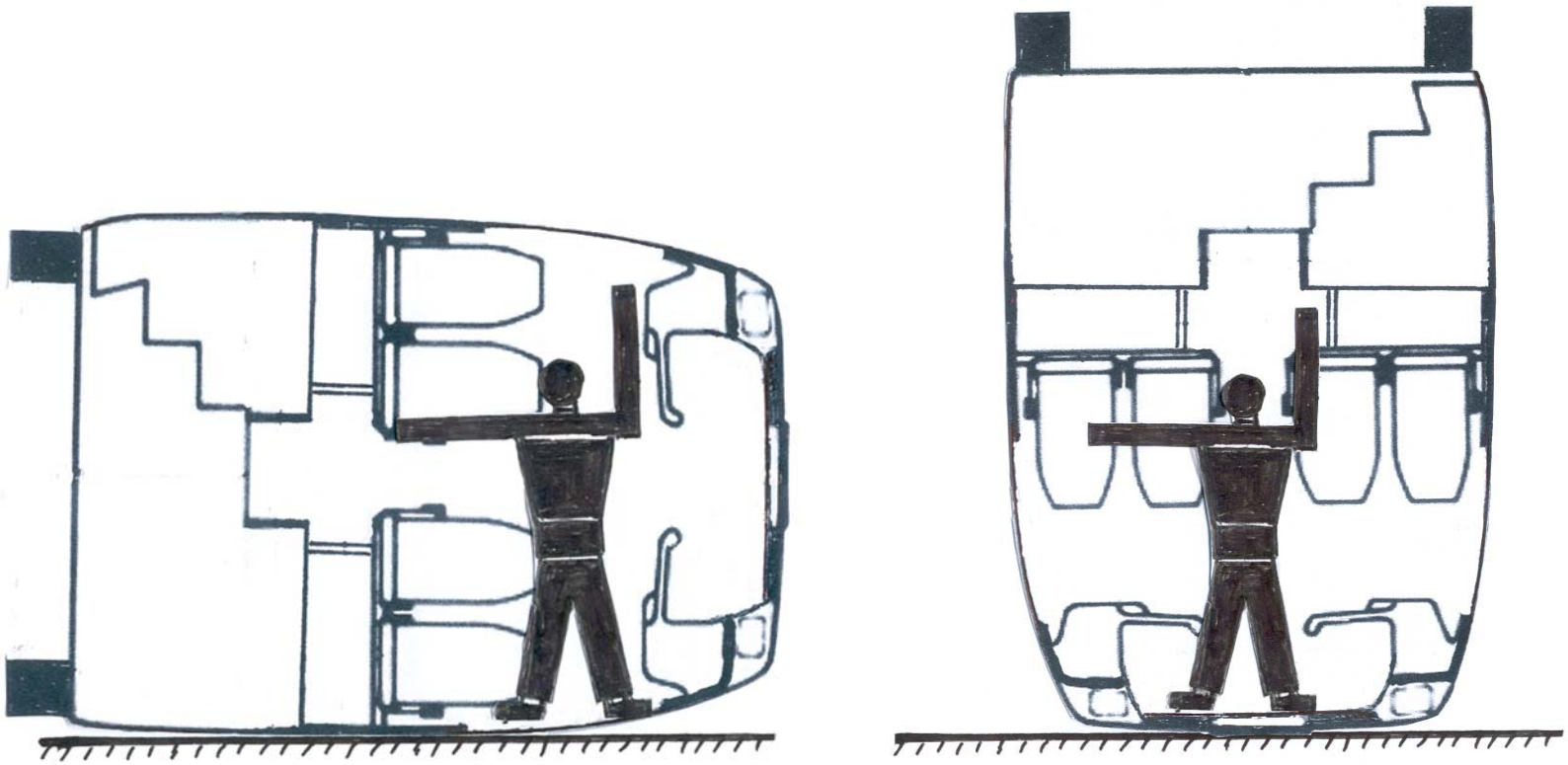
| Evacuation through | Large, single deck bus | | Double deck bus | | Small bus |
|---|---|---|---|---|---|
| | Low deck | High deck | Lower deck | Upper deck | |
| SD | very good | very good | very good | - | very good |
| ED | good | good | - | good | - |
| RD | - | - | - | - | good |
| SW | good | acceptable | good | very weak | good |
| RW | acceptable | weak | - | very weak | unusable |
| EH | very weak | very weak | - | very weak | acceptable |
| DD | weak | weak | weak | - | weak |
| WS | acceptable | acceptable | acceptable | very weak | - |

| | | | |
|---|---|---|---|
| SD | service door | RW | rear-wall emergency window |
| ED | emergency door | EH | escape hatch |
| RD | rear-wall door | DD | driver's cab door |
| SW | sidewall emergency window | WS | windscreen |

**Low deck** = waistrail height above the road is less than 1,8 m

**High deck** = waistrail height above the road is more than 1,8 m

# EVALUATION OF EMERGENCY EXITS



Passengers in different bus positions

# EVALUATION OF EMERGENCY EXITS

## The bus is standing on its roof (after ½ rotation)

| Evacuation through | Large, single deck bus | | Double deck bus | | Small bus |
|---|---|---|---|---|---|
| | Low deck | High deck | Lower deck | Upper deck | |
| SD | good | good | acceptable | - | very good |
| ED | good | good | - | good | - |
| RD | - | - | - | - | good |
| SW | good | good | good | good | good |
| RW | good | good | - | good | unusable |
| EH | unusable | unusable | - | unusable | unusable |
| DD | acceptable | acceptable | acceptable | - | weak |
| WS | very good | very good | - | very good | - |

SD service door
ED emergency door
RWD rear-wall door
SEW sidewall emergency window
RWEW rear-wall emergency window
EH escape hatch
DCD driver's cab door
WS windscreen

**Low deck** = waistrail height above the road is less than 1,7 m

**High deck** = waistrail height above the road is more than 1,7 m

# EVALUATION OF EMERGENCY EXITS

## The bus is lying on its door side

| Evacuation through | Large, single deck bus | | Double deck bus | | Small bus |
|---|---|---|---|---|---|
| | Low deck | High deck | Lower deck | Upper deck | |
| SD | unusable | unusable | unusable | - | unusable |
| ED | very weak | very weak | - | very weak | - |
| RD | - | - | - | - | good |
| SW | very weak | very weak | very weak | very weak | acceptable |
| RW | good | good | - | good | - |
| EH | very good | very good | - | very good | good |
| DD | very weak | very weak | very weak | - | very weak |
| WS | very good | very good | very good | very good | - |

| | |
|---|---|
| SD | service door |
| ED | emergency door |
| RD | rear-wall door |
| SW | sidewall emergency window |
| RW | rear-wall emergency window |
| EH | escape hatch |
| DD | driver's cab door |
| WS | windscreen |

**Low deck** = waistrail height above the road is less than 1,8 m

**High deck** = waistrail height above the road is more than 1,8 m

# EVALUATION OF EMERGENCY EXITS

## The bus is lying on the other side (not service door side)

| Evacuation through | Large, single deck bus | | Double deck bus | | Small bus |
|---|---|---|---|---|---|
| | Low deck | High deck | Lower deck | Upper deck | |
| SD | weak | weak | weak | - | good |
| ED | unusable | unusable | - | unusable | - |
| RD | - | - | - | - | good |
| SW | very weak | very weak | very weak - | very weak | acceptable |
| RW | good | good | - | good | - |
| EH | very good | very good | - | very good | good |
| DD | unusable | unusable | unusable | - | unusable |
| WS | very good | very good | very good | very good | - |

| | | | |
|---|---|---|---|
| SD | service door | RWEW | rear-wall emergency window |
| ED | emergency door | EH | escape hatch |
| RWD | rear-wall door | DCD | driver's cab door |
| SEW | sidewall emergency window | WS | windscreen |

**Low deck** = waistrail height above the road is less than 1,7 m

**High deck** = waistrail height above the road is more than 1,7 m

# DEVELOPED APPROACH TO EMERGENCY EXITS

To determine the required number and location of EE-s, the following should be considered:

- Passenger capacity of the bus
- separated passenger and driver's compartment
- possible after accident positions of the bus
- usability of different EE-s in different situations
- limited time in case of fire

# DEVELOPED APPROACH TO EMERGENCY EXITS

Available time for evacuation is case of fire 200-300 s

Evacuation times, when

- the bus is standing on its wheels
- 45-48 passengers on board
- passengers in normal position, no panic, no injuries

| | |
|---|---|
| through one service door (very good usability) | 40-80 s |
| through one emergency door (good usability) | 60-210 s |
| through one side window (acceptable usability) | 360-900 s |

# DEVELOPED APPROACH TO EMERGENCY EXITS

## Proposed requirements for the minimum number and location of EE-s

a) every separated passenger compartment in the four essential bus positions shall have:
   - up to 20 passengers min. 2, at least „acceptable” EE-s, among which one shall be „good” or „very good”
   - for 21-70 passengers min. 6, at least „acceptable” EE-s among which min. 2 shall be „good” or „very good”.
   - above 70 passengers additionally 2, at least „acceptable” EE-s are required

b) above the required number of „good” or „very good” EE-s, every extra „good” or „very good” EE shall be considered as 2 acceptable EE-s

c) the staircase to the upper deck in DD vehicles and the joint section in articulated vehicles may be counted as a „good” EE

# DEVELOPED APPROACH TO EMERGENCY EXITS

**Example:**

12 m long. Class III coach, 53 passengers on board, having:

| | |
|---|---|
| 2 service doors | SD |
| 1 rear wall emergency window | RW |
| 1 emergency door | ED |
| 3 escape hatches | EH |
| 2-2 sidewall emergency windows | SW |

Geometrical data:

| | |
|---|---|
| waistrail height above the road | 1750 mm |
| waistrail height above the seat-floor | 800 mm |

# DEVELOPED APPROACH TO EMERGENCY EXITS

In the example, the required number of EE-s

- min.6 at least „acceptable” EE-s, among which min. 2 EE-s shall be „good” or „very good”
- in every essential bus position

| EE-s | Standing on the | | Lying on the | |
|---|---|---|---|---|
| | wheels | roof | door side | other side |
| 2 SD | very good | good | - | - |
| 1 ED | good | good | - | - |
| 4 SW | acceptable | good | - | - |
| 1 RW | acceptable | good | good | good |
| 3 EH | - | - | very good | very good |
| 1 WS | acceptable | very good | good | acceptable* |
| good or very good | 3 | 9 | 5 | 4 |
| acceptable | 6 | 2 | - | 1 |
| requirements | met | met | met | met |

•-the driver’s cab should be considered as difficultly

# REMARKS

- The role of side windows is underrated: in two and half bus position they can not be used
- The breakable side windows should be omitted in the future
- The side windows could be made from laminated glass in respect to EE
- The EE-s shall be so designed and equipped with handles, grips and special devices which help the passengers to use them in all after accident positions
- The two decks of DD vehicles, in respect the EE-s are in vulnerable position:
  - upper deck, when the vehicle is standing on its wheels
  - lower deck, when the vehicle is lying on its side