

Bus fire and evacuation tests

1. BUS FIRE TESTS

1.1. IKARUS made three fire tests in the past with complete buses:

- IK 255 11 m intercity coach 1983
- IK 255 11 m intercity coach 1983
- IK 415 11,4 m local suburban bus 1988

1.2. The following fire types were simulated:

- Fire in the engine compartment (see Fig.1.);
- Fire in the dashboard (driver compartment) (see Fig.2.);
- Fire in the passenger compartment (only in IK255);
- Fire in the compartment of heating device (see Fig.3.).



Fig.1.: Engine compartment fire in IK 255



Fig.2.: Dashboard fire in IK 255



Fig.3.: Fire in the heating device compartment, IK 255

- 1.3. During the tests the following parameters were measured and observed:
 - temperature close to the fire and far from it ("close" means above the box of heating device, "far" means the rear part of the passenger compartment);
 - poison-gas concentration (CO, HCN, HCl);
 - the smoke and fire generation and propagation (by filming);
 - the effectiveness of fire-fighting.

- 1.4. Main test results when the fire started in the box of the heating device
 - Fig.4. shows the temperatures and gas concentrations (CO, HCl, HCN) as the function of time in the passenger compartment when the fire started under the floor, in the box of the heating device. The limit values of the critical gas concentration (L_x) are also shown on the figure.
 - In the two similar tests (IK 255, IK 415) the fire became detectable, observable (recognizing light smoke inside and outside the vehicle) in 4-5 minutes after the fire generation.
 - After the subjective recognition of the fire the measured values started to increase in 2-3 minutes and the smoke became dense in the bus.
 - After the recognition of the fire in 5-6 minutes the windows started to fall out and the new oxygen supply accelerated the fire. In 7-8 minutes the fire became general in the passenger compartment and the smoke was very dense and nontransparent.
 - After 11 minutes the fireman started to extinguish the fire with water from both sides of the bus. It took 7-8 minutes to put out the fire, but the buses were completely burned out, except the parts below the floor level, e.g. tyres, fuel tank, etc.

- 1.5. Some other experiences
 - Both the dashboard fire and the direct passenger compartment fire (started from a passenger seat) propagated very quickly and in 30-40 seconds the smoke was very dense, dark, nontransparent. After 1 min the fire propagated generally in every direction.
 - To extinguish these fires (before a general fire has been developed) by fireman, penetrating into the bus from outside and using foam fire extinguisher took 30-50 minutes.
 - The fire in the engine compartment needed 1-1,5 min. to be developed. In 2 minutes the fire could not go through the fire wall between the engine and passenger compartment. One standard fire extinguisher was not enough, two units were needed to extinguish the engine fire.
 - To extinguish a local fire in the box of the heating device (before it penetrated into the passenger compartment) needed one standard fire extinguisher.
 - The opening of the doors of engine compartment and the box of heating device, or the service doors, breaking the windows strongly accelerate the fire propagation.

- The IK 415 had power operated service doors. In the dashboard originated fire, in 90 seconds the first service door and its staircase was burning, in 3,5 minutes the electric control and air supply of the door operation system did not work anymore.

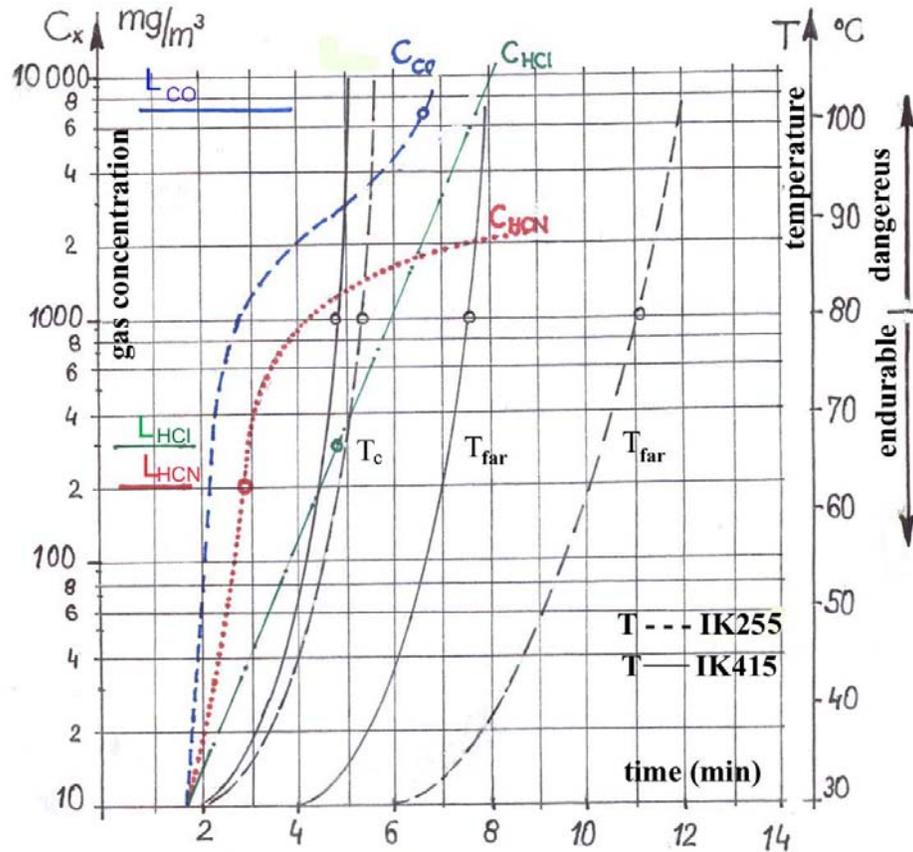


Fig.4.: Measured temperatures and gas concentrations in the test buses

2. EVACUATION TESTS (1984)

2.1. Characteristics of the bus

Type:	IKARUS 256
Category:	Class III intercity coach
Length:	11 m
Floor height:	940 mm
Number of seats:	45+1
Waist-rail height:	1750 mm
Service doors arrangement:	1-0-1
Service door width:	720 mm
Emergency door:	the rear service door was used, eliminating the steps by extending the floor to the door aperture.

2.2. Sample of "passengers" used during the tests:

- Professional, trained firemen, age 20-40 years;
- Adult persons (14 women, 30 men) age 25-45 years.



Fig.5.: Evacuation through two service doors



Fig.6.: Evacuation through all side windows

2.3. Different evacuation tests were carried out, using:

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|---|----------|
| – front service door, adult persons | 2 tests |
| – rear service door, adult persons | one test |
| – two service doors, adult persons (see Fig.5.) | one test |
| – rear emergency door, adult persons | one test |
| – front service door, firemen | 2 tests |
| – side windows, firemen, (see Fig.6.) | one test |
| – emergency window breaking the glass with safety hammer, 30 years old woman (see Fig.7.) | 2 tests |



Fig.7.: Evacuation through broken emergency window

2.4. Test conditions:

- the bus was full with occupants (45+1);
- the "passengers" were aware of what they had to do, there was no panic effect;
- on a given signal, all "passengers" started simultaneously the evacuation which was carried out in an organized, orderly way;
- the opening of the doors was made by the well-trained "driver";
- the fireman wore light uniform; the adult persons wore summer clothes without hand luggage.

2.5. The measured time intervals required for the complete evacuation of the bus are given in the Table I. below:

Table I.

Occupants	Methods of evacuation	Required time(s)
Fireman	Front service door	25-28
Adult persons	Front service door	37-40
Adult persons	Rear service door	40
Adult persons	Two service doors	20
Adult persons	Rear emergency door	54
Fireman	Through all side windows	10 <u>*/</u>

*/ Note: the fireman kicked out in the same moment all the side windows together with the rubber mounting and jumped out though the whole window frame (the windows were not broken).

The tests results, breaking the side window (emergency window) by hammer and escape from the bus:

- First test was unsuccessful, the hammer was not appropriate, the woman could not break the window.
- Second test with appropriate hammer:
 - Cracking the window 15 s
 - Creating a suitable size hole in the window, additional 25 s
 - Leaving the bus with help from outside, additional 50 s

The woman (30 years old) was afraid of jumping through the window which had glass fragments on the waistrail, therefore, she needed help from outside to jump out.

2.6. Estimated time intervals required to evacuate the test bus under the following conditions:

- the bus is fully loaded with passengers (wide range of age distribution);
- the event of the evacuation is unexpected, in the first moment the passengers don't know what to do;
- there is no severe injury on board, but there is a certain panic.

The estimated evacuation times are given in Table II:

Table II.

Way of evacuation	Evacuation time(s)
One single service door	100-120
Two single service doors	50-60
One double service door	70-90
One emergency door	150-180
Four emergency windows	300-400

- 2.7. Further information about bus evacuation tests (use of exists in emergency):
- TRANS/SC1/WP.29/GRSA/R.105 (12.12.1985) Evacuation of bus passengers: emergency exit systems. (Federal Republic of Germany);
 - Investigation into the ability of elderly people in climbing out of simulated bus emergency exits. Project report, March 1974, Industrial Ergonomics, Cranfield Institute of Technology. (presented in GRSA).

3. SOME GENERAL CONCLUSIONS

- 3.1. It is important to use fire walls between the passenger compartment and possible fire sources (engine compartment, box of heating device, wheel arches) with well specified requirements and test methods.
- 3.2. It is important to detect the fire in the possible fire sources (see above) using approved detectors with periodical inspections.
- 3.3. The opening of the doors of the fire sources (engine compartment, box of heating device) and the service doors, windows, if the passenger compartment is burning, accelerates the fire, the propagation becomes very rapid, uncontrollable.
- 3.4. In the case of power operated service doors – depending on the location of the fire in the passenger compartment – one or more service doors become operationally impaired because of the malfunction of the electric system and compressed air supply.
- 3.5. The local fires (engine compartment, box of heating device, dashboard, etc.) may be extinguished by the two standard fire extinguisher placed on the bus, but the general fire of the passenger compartment can be extinguished only by fire brigade, which takes 7-8 minutes.
- 3.6. It is important to know that in the case of a passenger compartment fire (the fire penetrated already and starts to propagate in this compartment) the most dangerous effects, in order of importance:
- smoke, the density of the smoke hindering the visibility and developing panic;
 - poisoning gases reaching the critical concentration;
 - temperature, reaching the critical value.
- 3.7. Strongly depending on the circumstances, from the early recognition of the fire (penetrating into the passenger compartment) there are 3-4 minutes, as an average, to evacuate the bus. This time seems to be enough, when:
- the fire is not the result of an accident;
 - there are no injured persons among the occupants;
 - there is no panic among the occupants;
 - service door(s) or emergency door may be used for the evacuation without any problem of their opening.
- 3.8. The emergency windows with breakable security glass are questionable solution in the case of fire, the needed time for the evacuation is too long (see Table II.) and the broken windows provide fresh oxygen supply to the fire.
- 3.9. The test results shown and analyzed here do not cover the most serious situation, when the fire is the consequence of an accident, there are injured passengers and panic on the board.
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