

Fire Investigation Report

by expert Maksim Smirnou

Analysis of Circumstances surrounding Case

On 7th of January 2005 fire discovered in detention room of Dessau Police Station caused death of Mr. Oury Jalloh. Deceased found chained to the wall and floor by his both hands and legs on reminds of burned mattress. It has passed 20 minutes between alarm off and the fire extinguished by fire brigade. Cigarette lighter was produced by policemen as source of ignition.



On the picture above deeply damaged skin of deceased burned to the muscles between legs and on right arm, fire amputation of three fingers of left hand. Mattress itself damaged deeply characterized to uniform temperature impact to all area. Absence of reminds not burned Polyvinylchloride "leather" of mattress including area facing floor. Absence of any reminds of Polyurethane foam in corners of the mattress, where flame front supposed to split up and would not be able to generate as high temperature as in middle of mattress and eventually burning process decays. Absence of remind of garment of deceased – presumably burned out. All above signs characterized to very flammable materials of the mattress involved in fire or high temperature impact same time involved all area of mattress, that described in literature {2, page 47} "flash over" situation, which occurs while all available fire load involved in burning process. Mattress only {2, page 35} has power (heat release rate HRR) 500-1000 kilowatts maximum. For accuracy we can calculate maximum heat release rate in our case mattress in detention room had size 1x2 meters so total area burned area is 2m². PVC "leather" at fire is charring and prevent spreading fire, hence calculations made for polyurethane foam only. According {7,8}, polyurethane foam has burning speed 0,0042 kg - 0,015 kg/(m² x sec) – from each meter square of burning area every second its burning out that weight of polyurethane foam. Full mattress from its area 2 m² in detention room loosing 0,0084-0.03 kg every second. Burning polyurethane is emitting 24,3x10⁶ joules per one kg. Maximum Heat release rate we can get multiplying

$$0.0084 \times 24,3 \times 10^6 = 199,26 \text{ kilowatts} \quad \text{or} \quad 0.03 \times 24,3 \times 10^6 = 729 \text{ kilowatts}$$

HRR needed to trigger flashover can be calculated if dimensions of walls, ceiling, windows and doors known.

Barbauskas formula: $Q_{fo} = 750 \times A_o \times (h_o)^{0,5} = 750 \times 0.95 \times 2.1 \times 2.1^{0,5} = 2168 \text{ kW}$ (open door)

Thomas Correlation: $Q_{fo} = 7,8 \times A_t + 378 \times A_o \times (h_o)^{0,5} =$

$$= 7.8 \times 58.9 + 378 \times 2.0 \times 2.1^{0,5} =$$

$$= 1555 \text{ kW (open door)}$$

$$= 459 \text{ kW (closed door)}$$

$A_o = 0.95 \times 2.1 = 2.0$ area of open door; $h_o = 2.1\text{m}$ height opening; $A_t = 2 \times (4.5 \times 2.5 + 2.5 \times 2.6 + 4.5 \times 2.6) = 58.9$ total area of floor, walls and ceiling

Power of burning polyurethane foam of single mattress (HRR) without PVC “leather” possible to get flashover situation with closed door, otherwise it must be additional fire load especially with the condition of open door or ventilation on.

Chemical analysis of the burned mattress has not revealed traces of accelerants.

{3, page 182} As severity of fire damage increase likelihood of finding traces of accelerants decrease. Even in situations when it is clear that fire accelerant was used positive results may not be obtained.

The possibility of no detection of accelerants in reminds of burned materials after fire is known to fire investigators.

The autopsy of body of Mr. Oury Jalloh has revealed that particles of soot clinging to throat found but no carboxyhemoglobin discovered in victim’s blood. Cause of death of Oury Jalloh by pathologist is inhalation of hot gases. No high level of adrenalin in kidneys was discovered. Cyanides found in victim’s liver later.

{2, page 582} Inhalation of flame or very hot gases can also produce a rapidly developing edema (swelling) of the tongue and pharynx which produce same as asphyxiation. In such causes of death carbon monoxide level in victim’s blood may be quite low, especially if the victim was exposed to a sudden flash or flame early in the stage of the fire. A victim who suddenly opens door from cool, smoke-free room into hallway completely enveloped in flame is typical of such fatalities. ... Also instances of it are quite rare, the possibility of suicide by fire should not be discounted. Such suicides are often accomplished by pouring flammable liquid over oneself and then igniting with much. A low COHb (carboxyhemoglobyn) level in fire victim may indicate death resulted early in fire caused by massive incineration, inhalation of flame-hot gases, or mechanical trauma (crushing, burial in debris, explosion trauma).

Expert concludes that high temperature of fire has hit the area at the head of Mr. Oury Jalloh faster than dangerous toxic gas concentrations and smoke or both occurred at same time. For this reason decision made to do full scale tests and obtain toxic gases concentrations and temperature and pass results to pathologists.

Estimations for tests

{4} 50% Lethal Dose of Polyurethane (LD50) for rats is from 30.5 gram per cubic meter in well ventilated combustion at 30 min exposure and 2 weeks following observation.. 4% of lethal effects occurred because of combined action of CO and HCN (hydrocyanic acid).

Size of detention room, death of Mr. Oury Jalloh occurred, is 4.5x2.5x2.6 meters, total volume of air in room is 29.25 cubic meters. Total amount of polyurethane required to obtain LD50 in room is $30.5\text{gr/m}^3 \times 29.25\text{m}^3 = 892$ gram. Weight of full mattress presented for test is 6500 grams. It is enough to burn less than 13.6% of matt (approximately 1/7 of area of mattress) to obtain LD50 in full room. Smoke and toxic gas concentration is not spreading uniform immediately in space of room, and can be much higher in nearest to burning area of mattress. For example, for to obtain LD50 in 2 cubic meters of air over the mattress, it requires 61 gram of polyurethane, which is less than 1% of full mattress.

{5} It is noted that the hydrocyanic acid and nitric oxide is generally formed by combustion of organic compounds that contain nitrogen, such as wool, leather, synthetic fabrics. In addition, the combustion of any organic materials released carbon monoxide. Polyurethane foam, compared with other materials of organic origin, produces toxic products when exposed to higher temperatures. Hydrocyanic acid is the same at 700 ° C is determined only traces, but even at 850 ° C in air, the concentration is increased approximately 28 times, and at 1000 ° C - 50-fold, reaching a significant level only in these circumstances.

{7} At temperatures above 170 ° C polyurethanes begin to decompose to give off toxic volatile and flammable products. In the products of oxidative degradation and incomplete combustion polyurethanes contain isocyanate fumes, hydrogen cyanide, nitric dioxide and carbon, methane, ethane, butane and other saturated and unsaturated hydrocarbons. Concentration iso-cyanate vapor and hydrogen cyanide is high and poses a risk to human life.

From sources above it is clear that cyanic acid is product of very high temperature or can be produced at over 170°C. In the initial stage of the development of fire hazardous to human factors are: the flames, the heat, the intensity of thermal radiation, toxic products of combustion, smoke, reducing the oxygen content in the air, because at certain levels they hit his body, especially at synergistic effects.

Studies of domestic and foreign scientists found that the maximum temperature tolerated man in a dry atmosphere is 149 °C, in a humidified atmosphere of second degree burns caused by exposure to a temperature of 55 °C for 20 s and 70 °C when exposed for 1 s, and the density of radiant heat flux 3500 W/m² is almost instantly burns airways and exposed skin, the concentration of toxic substances in the air are fatal: carbon monoxide (CO) to 1.0% (10000 ppm) for 2-3 min, carbon dioxide (CO₂) 5% 5 min. hydrogen cyanide (HCN) in 0.005% (50 ppm) almost instantly, with a concentration of hydrogen chloride (HCL) 0,01 - 0,015% (100-150 ppm) stops breathing, while reducing oxygen concentration in the air from 21% to 16% of the body worsen motor function, and muscle coordination disturbed to such a degree that independent movement of people becomes impossible, and the reduction of the oxygen concentration to 9% leads to death within 5 minutes.

The combined effect of several factors increases their impact on the human body (a synergistic effect). Since the toxicity of carbon monoxide in the presence of smoke increases, ambient humidity, decrease the oxygen concentration and increasing temperature. The synergistic effect observed and the joint action of nitrogen dioxide and the decreasing concentration of oxygen at elevated temperature, and under the combined action of hydrogen cyanide and carbon monoxide.

The special effects in humans has smoke. Smoke is a mixture of unburned carbon particles having a particle size of from 0.05 to 5.0 microns. On these particles are condensed toxic gases. Therefore smoke exposure on human and has apparently synergistic effect.

Tests

Ten mattresses for test were ordered size 2x1.2x0.08 meters consists of Polyurethane Foam covered by Polyvinyl Chloride skin to make full scale fire tests and detect temperature and toxic gas concentrations progress while fire development initiating of cigarette lighter with and without accelerants. Metal shed size 5x3x2.1-1.9 meters was built on grounds of Kilcaragh Park, Grantstown, Co. Waterford, Ireland. The heat insulation inside shed made and the wall along the left side was built of blocks in the middle, covered by ceramic tiles not grouted. Two smoke filtration units were used to improve visibility for video recording and reduce smoke environmental impact. Draeger X-am 5000 series testers were used to detect concentrations of CO, CO₂, NO, NO₂, HCl, O₂, NH₃, HCN, Cl₂ and CCl₂O. Eight "K-type"

thermocouples connected to "Novus" field logger used to detect temperature.

Ppm – particles per million;

°C degree celcium

Quarter mattress test 18/05/2013.

Ignition in two spots beside tiled wall. Door closed 1 min after ignition and reopened 6 min after.

<http://youtu.be/68dYg2pHWZA>

<http://www.youtube.com/watch?v=SvEQIkYfwI>

CO concentration excided in 2 minutes dangerous (A1=600 ppm) in 3 minutes was at maximum 995 ppm. CO₂ and HCl (mlast easured 4 meters from mattress) crossed A1 limit in 3 min, HCN below A1 limit with about 6 ppm in 3 min. Complete burned out part of mattress in the middle with reminds of PVC on perimeter of the sample, not burned Polyurethane foam in remote of the wall corners.



Three Quarter mattress test 30/05/2013.

Cuts made on PVC cover of mattress in middle of sample 20 centimeters to wall, fire set up by lighter in one point. Door was

closed after one minute imitating smoke alarm turned off cell ventilation system in detention room in Dessau. After 6 minutes door was opened imitating discovering fire by policeman. It has revealed that fire after spreading deep in mattress foam and to all directions has extinguished itself. PVC cover is burning hard and projecting about 0.7 to 1.5 centimeters over ellipsoid shape area of foam 21x11 x9cm burned out to the PVC cover on other side. Total volume of foam burned out is around 0,0025 meters cubic (2.5 liters).



P1. Moment of setting fire



P2. Burning area

With relatively small area burned out (not exceeding 1,5% full area of mattress) concentration of CO₂ in air was over 4 folds higher than dangerous for health (limit A2 recommended by Draeger), NH₃ over dangerous (limit A1), concentration O₂ fall dawn to about 16% (well below A1). Maximum of HCN concentration was 0.8 particles per million 12 folds less than A1 limit. Temperature same time was not over 30°C in one point of “Right Shoulder”. Other thermocouples produced lower result.

Full mattress with pig's body test 17/08/2013. Pig's body wrapped in jeans and T-shirt placed on mattress. Cuts made on PVC cover of mattress along the wall, fire set up by lighter in one point. Door was closed after one minute and opened after 20 min. After another 20 minutes it was discovered small area involved in burning at right lower paw and fire extinguished by water. It was revealed that fire after spreading deep in mattress foam and in all directions along cut stopped at right upper paw and extinguished after passing left lower paw. Totally burned out 1/3 area of the mattress. Pig's body received skin burns on right side and on lower paws. Part of jeans close to mattress burned completely, while top part reminds of jeans were not damaged. Totally burned out part of T-shirt on right side of upper part of body. CO level crossed A1 limit in 4 min, NH_3 , CHN and CCl_2O were just under $\frac{1}{2}$ of A1 almost all time of fire. "Walk in" after 30 min of fire started revealed dangerous concentration over A1 for NH_3 and over A2 limit for CHN and for CCl_2O 20 folds more than A2 concentration.



P1. Pig's body position after test



P2. Pig's body damage on right side



P3. Jeans damage



P4. Place where lighter was printed in PVC

Full mattress test with pig's body putting 200 ml ethanol spirit 18/08/2013 13.30 Pig's body wrapped in jeans and T-shirt placed on mattress. Cuts made on PVC cover of mattress between the wall and pig's body and on pig's other side. 100 ml of ethanol spilled on right side of pig's body and 100 ml spilled on left side. Fire set up by lighter in both parts. Door was closed after one minute and opened after 25 min. On the pictures below you can see, that the development of fire stopped on both sides of pig's body at places contacting mattress with upper and lower paws. In one minute after ignition CO₂ level overcome A2 dangerous concentration and reached 1.08%; CO and NO nearly reached A2 concentration 1080 ppm and 40.6 ppm. "Walk in" 25 min after fire started revealed dangerous concentrations of HCN and Phosgen CCl₂O.



P1. Pig's body before test



P2. Pig's body damage



P3. Mattress damage



P4. View of matt outside

Full mattress test with pig's body putting 750 ml BBQ lighter liquid
19/08/2013 18.00 Pig's body wrapped in jeans and T-shirt placed on mattress. Cuts made on PVC cover of mattress between the wall and pig's body and on pig's other side, 750 ml Barbeque Lighter Liquid (kerosene), sprinkled over mattress and pig's body. Fire was set up by lighter in both parts. Door was closed after one minute and opened after 35 min. On the pictures below you can see, that the development of fire stopped on both sides of pig's body at

places contacting mattress with upper and lower paws. In 2 minutes after ignition CO₂ level overcome A2 dangerous concentration and reached 1.46%; NO reached over A1 concentration 25.8 ppm, HCN overcome A2 limit and reached 30.9 ppm, CCl₂O overcame A2 concentration 48 folds and reached 9.6 ppm. NH₃, NO, Cl₂, CO and O₂ level have not reached A1 concentration. Temperature in area “right shoulder” and “right of head” in 2 min reached 200.2°C and 87.8 °C; in 3 min - 313.4 °C and 112.1 °C . _



P.1 View before test



P.2 After test



P3. Burned area beside wall

P4. Burned area on left side of pig's body

Full mattress test with pig's body putting 2000 ml petrol 20/08/2013 18.00

Full scale tests made on 20 August 2013, using 2 liters of petrol as liquid ignition accelerant. Cuts made on PVC cover of mattress around perimeter of mattress, PVC cover opened and approximately 1 liter of petrol sprinkled on polyurethane foam, then PVC cover placed in original position, two parts of pig's body and the head placed in middle of mattress. The lighter placed under pig's back. Another 1 liter of petrol sprinkled over pig's body and the head. Fire set up by lighter in the remote point of the wall in area of near the pig's lower left paw. The door of the shed after setting up fire kept open for 1 minute imitating working ventilation and fire would have enough oxygen to spread, then door was shut down imitating ventilation turned off by the fire alarm. After another 4 minutes door was reopened imitating discovering fire by policeman. After 30 minutes fire was extinguished by water.

Pictures of the results of the tests are on the left side, pictures taken from Oury Jalloh death are scene on the right side.

In spite of using at tests 2 liters accelerants liquid (petrol) there is some rests of fabric materials pig's body was wrapped in before test and also some parts of mattress survived at lower limbs location and on the left side of pig's body; while there is completely burned out material of mattress occurred in cell.



Cracked tile in middle of the wall achieved only in last test with petrol as accelerant never occurred using ethanol (spirit) or kerosene (barbeque lighter liquid) on previous tests, mattress connected to the wall in all tests, made strip of not covered by sod, there is no such strip on the wall in right picture of scene of Oury Jalloh's death, like it was possibly open space between mattress and the wall.



Complete deterioration of the pig's skin found in one place on the right upper paw and there are multiply deterioration spots on Oury Jalloh's body even in places with relatively small area of burned mattress like around left hand less

fingers, some places of the body like right arm skin burned out completely making visible muscles (see also pictures above).



There are some areas of the tested mattress in middle burned through completely producing nearly same result as on scene of death of Oury Jalloh, but no strip around perimeter of the mattress and no corners.



Concentrations of HCN (Cyanic acid) reached in 1 min over 2 folds over A2 limit 49.4 ppm, CCl_2O (Phosgen) over 25 folds over A2 limit 5.15 ppm, CO just over A2 limit 1270 ppm, NH_3 and CO_2 were between A1 and A2 concentrations 22 ppm and 0.9%. Concentrations of other gases were below

A1 limit. Temperature in area of right shoulder and right of the head was 375.5 °C and 201.2 °C in one minute after ignition.

Full mattress test with pig's body, upper PVC cover removed 01/11/2013 13.40

Full scale tests made on 1st of November 2013, removing upper part of PVC cover without accelerants. Two parts of pig's body bound with wires dressed in jeans and T-shirt and placed with the head in middle of mattress. The lighter placed under pig's back. PUR foam partly removed from area between legs and placed above right upper paw. The foam damaged between the wall and right upper paw, fire set up in same place by lighter. The door of the shed after setting up fire kept open for 1 minute, then closed for 3 minutes and opened.

<http://youtu.be/86gUhqIPL6M>

Flame front moves rapidly on PUR foam and burning out completely in original area. From video recording it is clear that in area of right upper paw intensive burning stopped after 3-4 minutes (6.05-10.05). Very slight charring of the pig's skin in that area occurred. No information in literature about time and temperature applied to human's body to get result of amputation, only {2, page 579} picture of the body after structure fire with hand amputation. Some sources mentioned, that in order to burn completely human's body in crematorium it is required 3-4 hours, but there is not information about hands, fingers amputation. Hence tests in crematorium required applying gas torch to hand only for 3-4 min. If amputation of fingers at test will not happen, than additional fire load was in area of right hand of deceased.

Gas concentration of CCl_2O only was nine folds over A2 - 1.87 ppm. NCN reached 6.5 ppm over half of A1 limit. CO was 24 folds less than A1 limit – 25 ppm.



P.1 Before test



P.2 After test



P.3 Cracked skin on right lower paw



P.4 Ashes of PVC cover of the mattress

Full mattress test with pig's body, upper PVC cover removed, 5 liters of petrol
05/11/2013 14.00

<http://youtu.be/jiqj5ft0wqY>

Full scale tests made on 5th of November 2013, removing upper part of PVC cover with 5 liters of petrol sprinkled. Two parts of pig's body bound with

wires dressed in jeans and T-shirt and placed with the head in middle of mattress. The lighter placed under pig's back. PUR foam partly removed from area between legs and near right upper paw. The foam damaged between the wall and right upper paw, fire set up in same place by lighter. With first minute fire converted to the jet out of opened door and was extinguished 3 min later. About half of tiles closed to the door displaced from the wall and cracked, pig's skin on the lower paws charred and cracked. CCl_2O (Phosgen) was over 35 folds over A2 limit - 7.05 ppm, NH_3 (ammonium) over 7 folds - 278 ppm, O_2 less than 10%, CO_2 two folds over A2 limit 2.12%, HCN - over A2 limit 26.2 ppm, Cl_2 over A1 limit 0.6 ppm, CO, NO, NO_2 below A1 limit 395 ppm, 8.3 ppm, and 1.1 ppm.

Conclusions.

1. Tests without accelerants revealed reminds of not burned fabrics of the pig's wrapping and very slight damage to the pig's skin. Various dangerous concentrations of toxic gases occurred, but no high level of HCN (cyanic acid) in burning products. Traces of cyanides found in the body of Mr. Oury Jalloh.
2. High concentration of HCN (cyanic acid) found in every test, using petrol and BBQ lighter liquid as fire accelerants. Temperature in area of the head can reach over 120°C in first minute while using accelerants.
3. The test using 2 liters of petrol as fire accelerant on 20.08.2013 is the most corresponding visually to the case of Oury Jalloh.
4. Concentration of CO (carbon monoxide) significantly reduced after removing upper layer of polyvinylchloride leather of the mattress and was not dangerous even while using 5 liters of petrol.
5. Heat release rate of polyurethane foam mattress is not enough for fire to envelope all area of the mattress to produce uniform damage. Tests with human body cremations required to reveal if additional fire load used in area of right hand of deceased.
6. All tests results must be reviewed by toxicologists and pathologists to define reason of the death of Mr. Oury Jalloh.

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