Robert Wilson Mayes,[1] Ph.D.

The Toxicological Examination of the Victims of the British Air Tours Boeing 737 Accident at Manchester in 1985

REFERENCE: Mayes, R. W., **"The Toxicological Examination of the Victims of the British Air Tours Boeing 737 Accident at Manchester in 1985,"** *Journal of Forensic Sciences*, JFSCA, Vol. 36, No. 1, Jan. 1991, pp. 179–184.

ABSTRACT: The results of toxicological analyses of the body fluids of the victims from the accident involving the British Air Tours Boeing 737 in August 1985 are presented for carboxyhemoglobin, cyanide, and volatiles.

All the victims except one had raised concentrations of carbon monoxide. All the victims had raised concentrations of cyanide. All the victims showed the presence of volatile substances in the blood. Autopsies revealed that all the victims had carbon particles in the trachea and bronchi. Thus, all the victims must have inhaled fire products in the burning aircraft cabin. Six victims had concentrations of carbon monoxide or cyanide in the blood that were neither fatal nor incapacitating; therefore, it is reasonable to suggest that these six victims survived for a comparatively short time and that there may have been other causes, in addition to toxic fumes, for their deaths. The other 48 victims must have survived long enough in the fire to accumulate incapacitating or fatal concentrations of carbon monoxide or cyanide or both. The effects of these substances found in the blood of each of the 48 victims must have combined to produce an insurmountable impediment to escape from the aircraft.

KEYWORDS: toxicology, aircraft, accidents

At 0715 hours on Thursday, 22 Aug. 1985, the British Air Tours Boeing 737-200, carrying 131 passengers and 6 crew members, started to take off from Manchester Airport in the United Kingdom. An explosion, followed by a fire, occurred in the port engine 32 s into takeoff. Thirty-one seconds after the explosion, the captain turned right, off the runway, and stopped. Unfortunately, the wind was blowing the smoke and flames from the burning port engine onto the rear fuselage of the aircraft. By the time the aircraft had stopped, witnesses observed that flame and smoke were entering the cabin, probably through the melted windows, and within 4 s it was black as night inside because the thick smoke. Most of the survivors escaped within 2 min, and by 2 min and 30 s after the explosion, dense smoke was coming out of the overwing exit and smoke was also coming out of the two front exits.

The airfield fire appliances were at the scene within 22 s of the aircraft coming to a halt, but such was the intensity of the fire that, 63 s after the explosion in the port engine, the tail section of the aircraft collapsed onto the runway.

Received for publication 17 Aug. 1989; revised manuscript received 26 Jan. 1990; accepted for publication 29 Jan. 1990.

[1]Squadron leader and officer in charge of toxicology, Department of Aviation Toxicology, Royal Air Force Institute of Pathology and Tropical Medicine, Aylesbury, Buckinghamshire, United Kingdom.

There are six exits from the fuselage of the Boeing 737. The rear port and starboard and port overwing exits could not be used because of the proximity of the fire. Only the front port and starboard and starboard overwing exits were available for escape. Fifty-two passengers and two cabin crew members, mostly seated towards the rear of the aircraft, were unable to escape and died in the fire. One passenger was recovered, unconscious but alive, only to die later in the hospital. The toxicology results for this victim are not included in this paper. The escape routes are detailed in Table 1. Because one victim was found alive, priority was given to potential lifesaving; thus, the positions of the dead in the aircraft are not known with certainty. It appears that 12 bodies were found in the rear section, 29 in the center section, 4 in the front section, 8 in their seats, and 1 in an unknown location.

It is clear from the evidence of passengers and firemen that the aircraft was penetrated by fire and filled with smoke in a very short time. It is probable that no one was capable of escape after about 2 min in the atmosphere produced by the fire. The unavailability of three of the six exits from the fuselage fatally increased the time it took for the passengers seated towards the rear of the aircraft to reach the available exits.

Toxicological Background

The toxicological investigation was designed to assist in discovering the manner of death of the 54 people who died in the aircraft. Purser [*1*], in his excellent paper "How Toxic Smoke Products Affect the Ability of Victims to Escape from Fires," cites carbon monoxide, hydrogen cyanide, low oxygen, and increased carbon dioxide as being responsible for severe narcosis and the deaths of victims overcome by smoke. Eye and upper respiratory tract irritation also impair escape, but to an unknown degree. Purser considers three fire scenarios: smoldering fires, early flaming fires, and fully developed post-flashover fires. The scenario that most nearly approximates this accident is the last type, in which the oxygen concentrations are low, the pyrolysis products break down into low-molecular-weight fragments, and the fire atmosphere can contain high concentrations of substances such as carbon monoxide and hydrogen cyanide. It was decided that measurements of the blood cyanide and carboxyhemoglobin saturation should be made. It was also decided that an examination for volatile chemical agents should be carried out on the blood since this might give additional information on the composition of the cabin atmosphere.

Methods

The carboxyhemoglobin was measured by gas chromatography using the method of Blackmore [*2*]. The cyanide was measured using an adaptation of the method of Feldstein and Klendshoj [*3*]. In this method, nitrogen was passed through acidified blood and the hydrogen cyanide liberated was trapped in alkali. The cyanide was estimated by measuring the optical density of the colored complex formed with chloramine-T and pyridine/bar-

TABLE 1—*How survivors escaped from the aircraft.*

Starboard direct vision window	2 flight deck crew
Port front exit	16 passengers, 1 cabin crew
Starboard front exit	37 passengers, 1 cabin crew
Starboard overwing exit	25 passengers

bituric acid solution. The method of Ramsey and Flannagan [4] was used to test for the presence of volatile substances.

Specimens

Postmortem specimens of blood were obtained from all the victims in fluoride-oxalate, heparin, and plain containers. Urine was also obtained in fluoride-oxalate and plain containers for most of the victims. The specimens were refrigerated until analysis was performed.

Results and Discussion

The results are summarized in Table 2.

Anderson et al. [5] suggest that the fatal threshold for carbon monoxide poisoning in fire death situations is 50% saturation of the total hemoglobin. Incapacitation levels are more difficult to assess, active subjects being seriously affected at saturation levels which have only minor effects on sedentary subjects. Experiments on primates suggest that carboxyhemoglobin concentrations in the 25 to 35% range would seriously affect the ability of a subject to do work. The concentration of incapacitation for carboxyhemoglobin is taken to be 30% saturation.

In this investigation, there were 21 male victims and 33 female victims; the average carboxyhemoglobin saturation was 30% for the males and 45% for the females. Thirteen victims (1 male and 12 female) had blood concentrations above the fatal threshold, taken to be 50%. Twenty-seven victims (9 male and 18 female) had saturations above the concentration producing incapacitation, taken to be 30%, but below the fatal threshold of 50%. Fourteen victims (11 male and 3 female) had carboxyhemoglobin saturations below the concentration taken to be incapacitating.

Although 50% saturation is taken to be fatal and 30% is taken to be incapacitating, it is probable that death may occur in individuals with saturation levels below the arbitrary 50% and that levels below 30% may be severely incapacitating.

One victim (3M) had a saturation of 8% carboxyhemoglobin. If concentrations in nonsmokers are taken to be 0 to 3% and concentrations in smokers are taken to be 3 to 10%, the level in 3M could have been due to smoking rather than to fire. However, as Dominguez [6] has described, survival in flaming fires following accidents may lead to carboxyhemoglobin saturations below 10%, with pathological findings consistent with death occurring as a result of exposure to fire. This may be because victims trapped in an intense fire or exposed to direct flame may suffer spasm of the laryngeal area and reduced circulation.

It is interesting to note that the female victims have significantly higher concentrations of carbon monoxide than the male victims. The higher carbon monoxide saturations are taken to indicate longer survival times in the fire atmosphere, but it must be remembered that the concentrations measured in postmortem specimens are the concentrations reached when death occurs. Inevitably, collapse and further inhalation would occur before this time, and so the concentrations of toxic substances in the blood would increase until death occurred.

Similar difficulties are encountered when trying to assess the effects of hydrogen cyanide. In fire death situations, serious risk to life is said to occur at blood concentrations of 270 μg/100 mL [7]. It is believed that toxic effects begin at about 135 μg/100 mL. There was a mean blood cyanide concentration of 275 μg/100 mL for the male victims and a mean of 274 μg/100 mL for the female victims. It is interesting to note that there is no large difference between the male and female blood cyanide concentrations, although there is a considerable difference between the male and female carboxyhemoglobin

TABLE 2—*Summary of toxicological results for victims.*[a]

Body	Carbon Monoxide, % saturation	Cyanide, μg/100 mL	Benzene, mg/L	Toluene, mg/L
1F	38	158	0.39	0.04
2F	45	190	0.32	0.08
3M	8	74	0.02	ND
4F	34	203	0.25	0.05
5F	15	179	0.02	ND
6F	40	91	0.55	0.09
7F	49	290	0.32	0.07
8F	25	145	0.57	0.14
9F	41	70	0.66	0.10
10M	24	53	0.31	0.05
11F	36	300	0.30	0.07
12M	42	300	1.30	0.24
13F	45	250	0.42	0.09
14M	23	150	0.16	0.04
15M	17	168	0.10	ND
16F	32	88	0.56	0.09
17M	31	540	0.58	0.09
18M	41	170	0.34	0.07
19M	45	250	1.17	0.18
20F	44	520	0.74	0.12
21M	22	480	0.22	0.04
22M	23	183	0.13	ND
23F	46	200	0.53	0.08
24F	38	233	0.39	0.08
25F	42	450	0.16	0.03
26M	44	350	0.20	ND
27M	35	200	0.56	0.14
28F	54	260	0.18	0.06
29M	43	550	0.33	0.05
30F	54	240	0.44	0.07
31M	25	450	0.05	ND
32F	40	250	0.81	0.21
33F	53	185	0.70	0.07
34M	22	120	0.22	0.04
35F	39	190	0.24	0.06
36M	28	125	0.46	0.06
37F	20	73	0.02	ND
38F	50	335	0.50	0.07
39F	62	240	0.37	0.07
40F	61	315	0.47	0.04
41F	51	400	0.78	0.19
42M	25	560	0.09	0.02
43F	54	370	0.45	0.07
44F	35	55	0.29	0.06
45F	41	190	0.68	0.11
46M	22	115	0.08	0.01
47F	79	840	1.08	0.19
48M	52	680	1.73	0.38
49F	65	430	0.57	0.16
50F	68	500	1.59	0.24
51M	30	195	0.35	0.04
52F	38	500	0.29	0.05
53F	61	310	0.89	0.12
54M	40	65	0.33	0.06

[a] Key to abbreviations:
F = female.
M = male.
ND = not detected.

concentrations. Twenty-one victims (13 female and 8 male) had concentrations above the fatal threshold, taken to be 270 μg/100 mL. Twenty-two victims (15 female and 7 male) had concentrations above the level of incapacitation but below the fatal threshold. Eleven victims (5 female and 6 male) were found to have concentrations below that thought to be incapacitating.

Conclusions may be drawn using blood cyanide concentrations which suggest longer or shorter survival times in the cabin atmosphere. However, the cyanide parameter must be considered less reliable than the carbon monoxide one. This is because of the uncertainty as to the loss or production of cyanide during storage of postmortem blood and because the method of analysis is less reliable than that employed in carbon monoxide estimation.

Anderson and Harland [7] indicate that normal blood cyanide concentrations are about 20 μg/100 mL. Thus, assuming no postmortem production of cyanide had occurred, all the victims had raised blood cyanide concentrations.

The screening for volatiles showed that the major compounds present were benzene and toluene, which presumably originated in the combustion of plastics and cabin furnishings. There was a mean of 0.47 mg/L for benzene and of 0.08 mg/L for toluene in the blood of the victims.

Conclusions

All the victims had raised concentrations of carbon monoxide except body 3M. All the victims had elevated concentrations of blood cyanide. All the victims had volatiles in their blood. All the victims had carbon particles in the trachea and bronchi. Thus, all the victims inhaled some fire products. Six victims (3M, 10M, 34M, 36M, 37F, and 46M) had less than the arbitrarily fixed incapacitating concentrations of both carbon monoxide and cyanide, and it is reasonable to suggest that these victims survived for shorter times than the remaining 48 victims in the fire atmosphere. The remaining 48 victims had fatal or incapacitating concentrations of carbon monoxide or hydrogen cyanide because of their inhalation of toxic combustion products. It is reasonable to propose, on the toxicological evidence, that most of the passengers did not escape because they were overcome by the effects of toxic gases and smoke before they were able to reach the available escape exits. The remaining six victims may have had factors in addition to toxic fumes playing a major role in bringing about their deaths.

Acknowledgment

The author is grateful to the Director General of the Royal Air Force Medical Services for permission to publish this paper.

References

[1] Purser, D., "How Toxic Smoke Products Affect the Ability of Victims to Escape from Fires," *Fire Prevention,* May 1985, pp. 28–32.

[2] Blackmore, D. J., "The Determination of Carbon Monoxide in Blood and Tissue," *The Analyst,* Vol. 95, 1970, pp. 439–458.

[3] Feldstein, M. and Klendshoj, N. C., "The Determination of Cyanide in Biological Fluids by Microdiffusion Analysis," *Journal of Laboratory and Clinical Medicine,* Vol. 44, 1954, pp. 166–170.

[4] Ramsey, J. D. and Flannagan, R. J., "Detection and Identification of Volatile Organic Compounds in Blood by Headspace Gas Chromatography as an Aid to the Diagnosis of Solvent Abuse," *Journal of Chromatography,* Vol. 240, 1982, pp. 423–444.

[5] Anderson, R. A., Watson, A. A., and Harland, W. A., "Fire Deaths in the Glasgow Area: II. The Role of Carbon Monoxide," *Medicine, Science and the Law,* Vol. 21, 1981, pp. 288–294.

[6] Dominguez, A. M., "Symposium—Fire and Incendiarism," *Journal of Forensic Sciences,* Vol. 7, 1962, pp. 379–393.
[7] Anderson, R. A. and Harland, W. A., "Fire Deaths in the Glasgow Area: III. The Role of Hydrogen Cyanide," *Medicine, Science and the Law,* Vol. 22, 1982, pp. 35–40.

Address requests for reprints or additional information to
Squadron Leader Robert W. Mayes, Ph.D.
Department of Aviation Toxicology
Royal Air Force Institute of Pathology and Tropical Medicine
Halton, Aylesbury
Buckinghamshire
United Kingdom HP22 5PG