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## Two Deaths Caused by a Lack of Oxygen in an Underground Chamber

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Asphyxial deaths caused by a gross deficiency of oxygen and associated with elevated levels of carbon dioxide are relatively rare. Most such deaths are industrial accidents. The typical case occurs when an individual descends into a sewer, brewery vat, or mine that has not been ventilated for some time. In some of these cases, especially those occurring in sewers, death may be due to other gases such as methane or hydrogen sulfide. Therefore, for proper interpretation of these deaths, it is essential to specifically identify the gas or gases that caused death. Herein are presented two deaths in an underground chamber caused by a gross deficiency of oxygen and associated with an elevated concentration of carbon dioxide. Both these conditions were the direct result of primitive forms of plant life and funguslike organisms growing in the chamber, consuming the oxygen, and producing carbon dioxide.

### Case Report

At approximately 9:15 a.m. on 2 Oct. 1969, a six-man crew of employees of the Department of Water Resources of the City of New York arrived at the site of an underground water valve vault in the Borough of Brooklyn. The Department of Water Resources has a policy of inspecting all water valves at least once a year. The particular vault to be inspected had been constructed approximately 65 years earlier. It contained a valve located on a 48-in. diameter water main. The vault, located directly under a street, consisted of a chamber 6 ft high by 5 ft wide by 12 ft long with a concrete floor and brick walls. Access was gained through a manhole 2 ft in diameter which was flush with the overlying roadway. The manhole concealed a 3 ft deep by 2 ft wide cylindrical antechamber which in turn opened up into the roof of the vault. A ladder ran from the manhole to the floor of the chamber.

Shortly after the arrival of the crew, the manhole was opened and a 50-year-old male employee climbed down the ladder into the vault. On reaching the bottom of the vault, he was seen to collapse. A fellow employee immediately climbed down the ladder to rescue him but had to be helped out when he began to feel faint. A second rescue attempt was unsuccessful with this individual also having to be pulled out of the vault.

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At approximately 9:25 a.m. a police officer assigned to the Police Emergency Rescue Patrol arrived. The officer, wearing a self-contained cannister type gas mask, descended into the vault and collapsed. Shortly thereafter a member of the fire department equipped with a different type of gas mask descended into the vault and recovered both bodies. Both individuals were dead on arrival at a nearby hospital. The fireman's mask differed from the police officers in that his was outfitted with an air hose fed from ground level by a pump.

After recovery of the two men, the vault was sealed. At 10:35 a.m., approximately one hour after the fatal sequence of events started, a sample of air was removed from the vault for analysis by the Brooklyn Union Gas Company.

The two bodies were brought to the Office of the Chief Medical Examiner in Brooklyn where complete autopsies were performed. The autopsy findings were unremarkable in both cases.

### Discussion

The cause of death in these two cases was initially thought to be asphyxia by methane gas. Methane, the principal constituent (94 to 96 percent) of natural gas, has no specific toxicity but, like carbon dioxide, can cause death by displacing oxygen. The effect of both methane and carbon dioxide is proportional to the amount of oxygen they displace in the air that is breathed. Oxygen must be diminished to two thirds of its normal percentage before appreciable symptoms develop. Such a decrease would require a methane or carbon dioxide concentration of 33 percent in the air. Reduction of oxygen to a concentration of 50 percent of normal causes marked symptoms, with reduction to 25 percent causing death in a matter of minutes [1].

Methane was presumed to be the toxic agent when an initial report by the gas company on the day of the deaths indicated that ethane had been detected in the sample of air removed from the vault. Detection of ethane, a minor component (2.5 to 3.5 percent) of natural gas, almost invariably indicates the presence of natural gas. A subsequent more detailed analysis, however, revealed that methane constituted only 3.4 percent of the vault air. Of more significance was the fact that there was a striking deficiency of oxygen accompanied by a marked increase in carbon dioxide (Table 1) [2]. Oxygen (which normally makes up approximately 21 percent of the air) constituted only 11.4 percent of the vault atmosphere while carbon dioxide (which is usually 0.033 percent) was 5.7 percent. These figures are even more striking if one realizes that the vault had been opened to the outside air for a significant amount of time—during the deaths and attempts at rescue—before the sample was collected.

An air sample obtained from the vault the day after the deaths (Table 2) revealed the percentage of oxygen to have dropped to 9.6 percent while carbon dioxide rose to 7 per-

TABLE 1—Results of an analysis of the air sample removed from the vault on the day of the deaths compared to normal air.

Constituent	Vault Air Content, Percent by Volume	Normal Air Content, Percent by Volume
Nitrogen	78.5	78.084
Oxygen	11.4	20.946
Carbon Dioxide	5.7	0.033
Methane	3.4	...
Argon	0.94	0.934
Ethane	0.012	...

TABLE 2—Results of an analysis of a sample of vault air taken 3 October, the day after the deaths.

Constituent	Content, Percent by Volume
Nitrogen	80.4
Oxygen	9.6
Carbon Dioxide	7.0
Methane	2.0
Argon	0.95
Ethane	0.003

cent [2]. Analysis of the oxygen content from several neighboring manholes that had not recently been opened produced oxygen concentrations as low as 2 percent [2].

The results of these chemical analyses indicated that death was due to a gross deficiency of oxygen associated with a markedly elevated concentration of carbon dioxide. The important question that now arose was what caused this lethal atmosphere.

There were several factors that indicated natural gas did not play a role in the deaths. If the lethal nature of the atmosphere in the vault had been due to leakage of natural gas, all the components of normal air would have had their concentrations reduced proportionately. Thus, if the concentration of oxygen was reduced by half, the concentration of nitrogen would also have been reduced by half. Analysis of the samples from the vault did not show this, however. While the concentration of oxygen was markedly reduced, those of nitrogen and argon were close to normal levels (Tables 1 and 2). In addition, if the reduction in the oxygen concentration was to almost half normal value, that would indicate that approximately half the air had been displaced by natural gas. This in turn would mean that the concentration of methane would be approximately 50 percent. Analysis of the vault atmosphere, however, never revealed a methane concentration greater than 5 percent.

There was, of course, no question that methane was present in the atmosphere of the vault. The source of the methane was first thought to be a leak in a gas pipe. However, if the methane was due to a leakage of natural gas, then the proportion of methane to ethane would have been approximately 30 to 40:1. This is because natural gas is made up of 94 to 96 percent methane and 2.5 to 3.5 percent ethane [2]. Tables 1 and 2 revealed that the actual proportion of methane to ethane was several hundred to one. Therefore, except for an extremely small amount, the bulk of the methane was not from natural gas. There had to be some other source for it.

Examination of the vault revealed a funguslike growth on the walls and a thick organic sediment on the floor. Sediment from the floor and similar funguslike material removed from the side of a neighboring manhole were placed in three airtight containers. These containers were kept in the dark to simulate the vault environment. Within a day, the oxygen concentration in these containers fell to 16.2 percent, 19.1 percent, and 0.051 percent, respectively, while the carbon dioxide levels rose to 5.1 percent, 2.6 percent, and 18.2 percent, respectively [2]. Small amounts of methane were detected in all three containers. These tests indicated that the lethal atmosphere in the vault was due to the metabolic processes of the fungi and plant life with production of carbon dioxide and methane and utilization of oxygen by these organisms.

Further proof of this conclusion was obtained from a further series of analyses carried out on air from the vault [2]. The vault was vented on 7 October and then sealed. Daily tests were then conducted to determine the levels of oxygen and carbon dioxide (Table 3).

TABLE 3—Results of analysis of serial samples of vault air.

Date Sample Taken	Oxygen Content, Percent by Volume	Carbon Dioxide Content, Percent by Volume
8 October	19	0.8
10 October	18	1.4
14 October	15.8	3.3

These showed a steady drop in oxygen concentration in conjunction with a steady rise in carbon dioxide. Thus, only one week after the vault had been vented, the atmosphere was again approaching the dangerous state.

During the course of the investigation the question arose as to why the police officer who was wearing a cannister gas mask died. The answer to this lay in the type of mask used. The cannister contained lithium hydroxide which filters the carbon dioxide out of the air the wearer inhales. It does not, however, provide oxygen. Therefore, when the police officer descended into the vault he died from lack of oxygen—a circumstance for which his mask did not provide any protection.

### Summary

Two persons, an employee of the Department of Water Resources and a police officer, were asphyxiated in an underground water valve vault. The two deaths were caused by a gross deficiency of oxygen associated with an elevated level of carbon dioxide. This lethal atmosphere produced rapid loss of consciousness and death within a matter of minutes. The atmosphere was produced by funguslike organisms and low forms of plant life present on the vault walls and in the sediment on the floor. The small amount of methane gas present was felt to have played no part in the deaths and to have been produced by the same biological processes that resulted in the lethal atmosphere.

### References

- [1] Sax, N. I., *Dangerous Properties of Industrial Materials*, 3rd ed, Van Nostrand Reinhold Co., New York, 1968.
- [2] "Report on the Death of Two Persons in a Water Valve Vault at Eastern Parkway and Troy Avenue, Brooklyn, on October 2, 1969," staff report to the Public Service Commission, State of New York, 1969.

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