Nitrous Oxide: By No Means a Laughing Matter

by Derek Davenport

A recent news item in the *Chicago Tribune* read in its entirety:

Getting high from laughing gas, or nitrous oxide, can be dangerous, especially if the gas is inhaled from large tanks, according to Drs. Richard H. Schwartz and Martha Calihan of the Medical College of Virginia. Such tanks are sold in automotive shops to boost the performance of hot rods, they reported in the journal *American Family Physician*. Dangers include freezing of the user's lips and mouth if the gas is inhaled directly from the cylinder, lung damage if the gas is under high pressure, brain injury from lack of oxygen, and head injury if the user passes out and falls.

From the properly cautionary tone of this note, one would hardly guess that nitrous oxide (N_2O) was historically the first inhalation anesthetic and remains today one of the safest and most widely used.

Nitrous oxide was first isolated by Joseph Priestley (1733–1804) from the exothermic reaction of nitric oxide gas with moist iron filings:

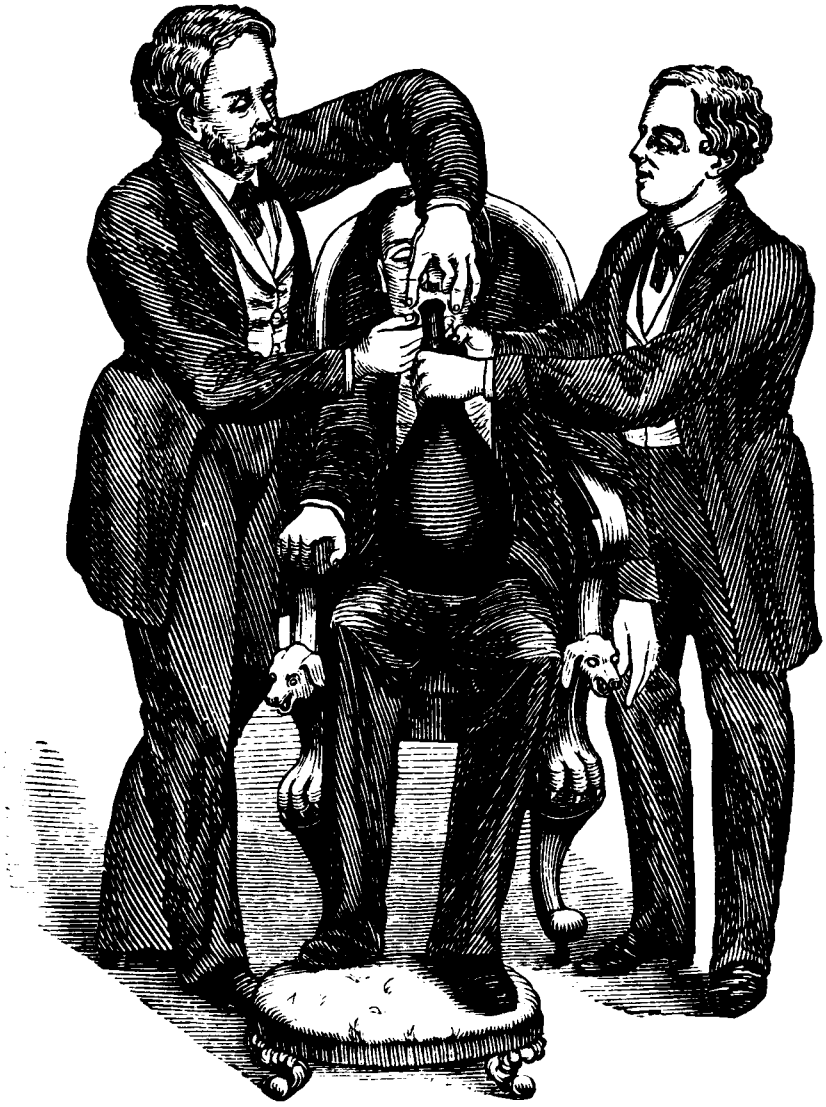
$$2\,NO(g) + Fe(s) \longrightarrow FeO(s) + N_2O(g)$$

Priestley noted its moderate solubility in water, its sweetish smell, and its surprising effect on a glowing splint. When he exposed a red-hot piece of wood to nitrous oxide, the wood burst into flame. This unusual property is found in only one other common gas, oxygen. (To keep the different oxides straight, see box, Some oxides of nitrogen.)

About the same time that Priestley was isolating nitrous oxide, Joseph Black (1728–1799) in Edinburgh was demonstrating to his medical students the strange properties of a gas obtained by heating a concentrated solution of ammonium nitrate:

$$NH_4NO_3(aq) \longrightarrow N_2O(g) + 2H_2O(l)$$

This method is still in use for the commercial preparation of nitrous oxide. Because the ammonium cation is a good reducing agent and the nitrate anion is a good oxidizing agent, it should not be surprising that the decomposition of ammonium nitrate is strongly exothermic (releases energy). Indeed, in 1947, the explosion of a ship loaded with 1400 tons of ammonium nitrate fertilizer was the initial cause of the Texas City disaster, one of the worst accidents in U.S. industrial history.



Because N_2O was the first gaseous anesthetic, it had to be administered with improvised equipment. Here, a dentist holds the patient's nose while an assistant administers nitrous oxide from an animal bladder.

Some oxides of nitrogen

N_2O	**Nitrous oxide** (dinitrogen monoxide)—laughing gas
NO	**Nitric oxide** (nitrogen monoxide)—colorless gas, used to make nitric acid
NO_2	**Nitrogen dioxide**—red-brown poisonous gas, present in smog
N_2O_4	**Dinitrogen tetroxide**—colorless gas, formed from NO_2

Human guinea pig

One of the medical students who attended Black's lectures was Thomas Beddoes (1760–1808), who founded a "pneumatic institute" to

study the treatment of disease, particularly tuberculosis, by the breathing of gases. He hired the young chemist and aspiring poet, Humphry Davy (1778–1829), as superintendent. Davy carried out a long, and at times hair-raising, series of research, often using himself as a guinea pig.

One of the gases Davy studied was "hydrocarbonate"—a toxic mixture containing carbon monoxide and hydrogen now known as water gas. In spite of the death of several pigeons in a preliminary experiment, Davy recklessly tried it on himself. He was lucky to survive. It can't be said that he learned from his experience because shortly afterward we find him trying to squeeze all the air out of his lungs so he could fill them with nitric oxide. However, no matter how hard one exhales, considerable air always remains in the lungs. Thus, when Davy breathed nitric oxide, NO, the residual air immediately converted it to nitrogen dioxide, NO_2, which in turn dissolved in body fluids to give an acidic solution in his lungs:

$$2NO(g) + O_2(g) \longrightarrow 2NO_2(g) \xrightarrow{H_2O} HNO_3(aq) + HNO_2(aq)$$

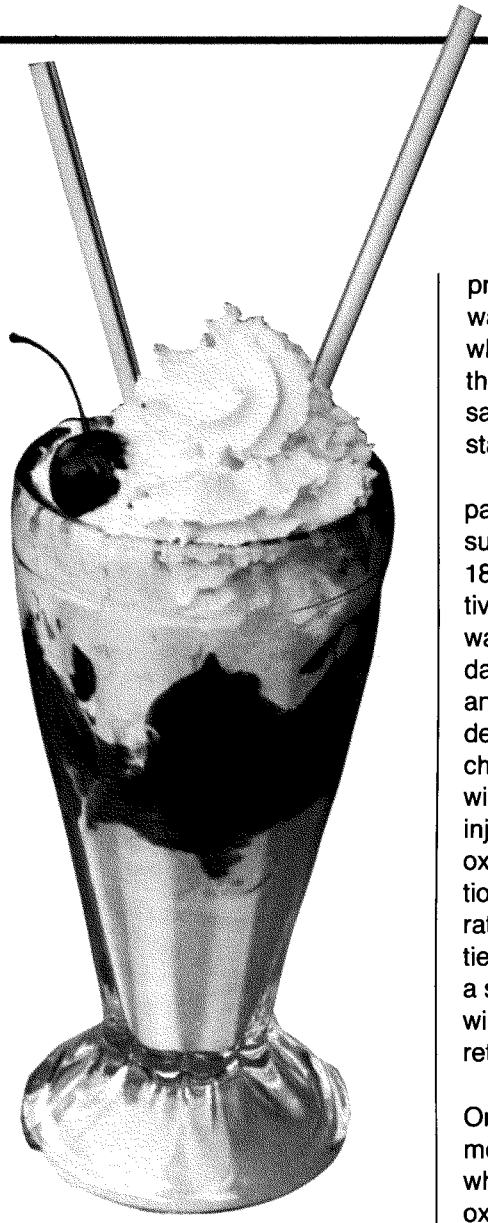
Davy's most agreeable results were achieved by breathing Priestley's nitrous oxide:

> a fullness of the heart accompanied by a loss of distinct sensation and of voluntary power, a feeling analogous to that produced in the first stage of intoxication . . .

succeeded by a "highly pleasurable thrilling" and later by "a disposition to muscular motion and merriment." Thus was the name "laughing gas" born. The inhalation of nitrous oxide became a fad. Laughing gas parties and public demonstrations were enthusiastically attended.

Wisdom without pain

Davy also noted that pain associated with cutting a wisdom tooth "was for a few minutes swallowed up in pleasure." He later remarked, "It may probably be used with advantage during surgical operation in which no great effusion of blood takes place."



Nitrous oxide is used as the propellant in canned whipped cream because it dissolves readily in fats.

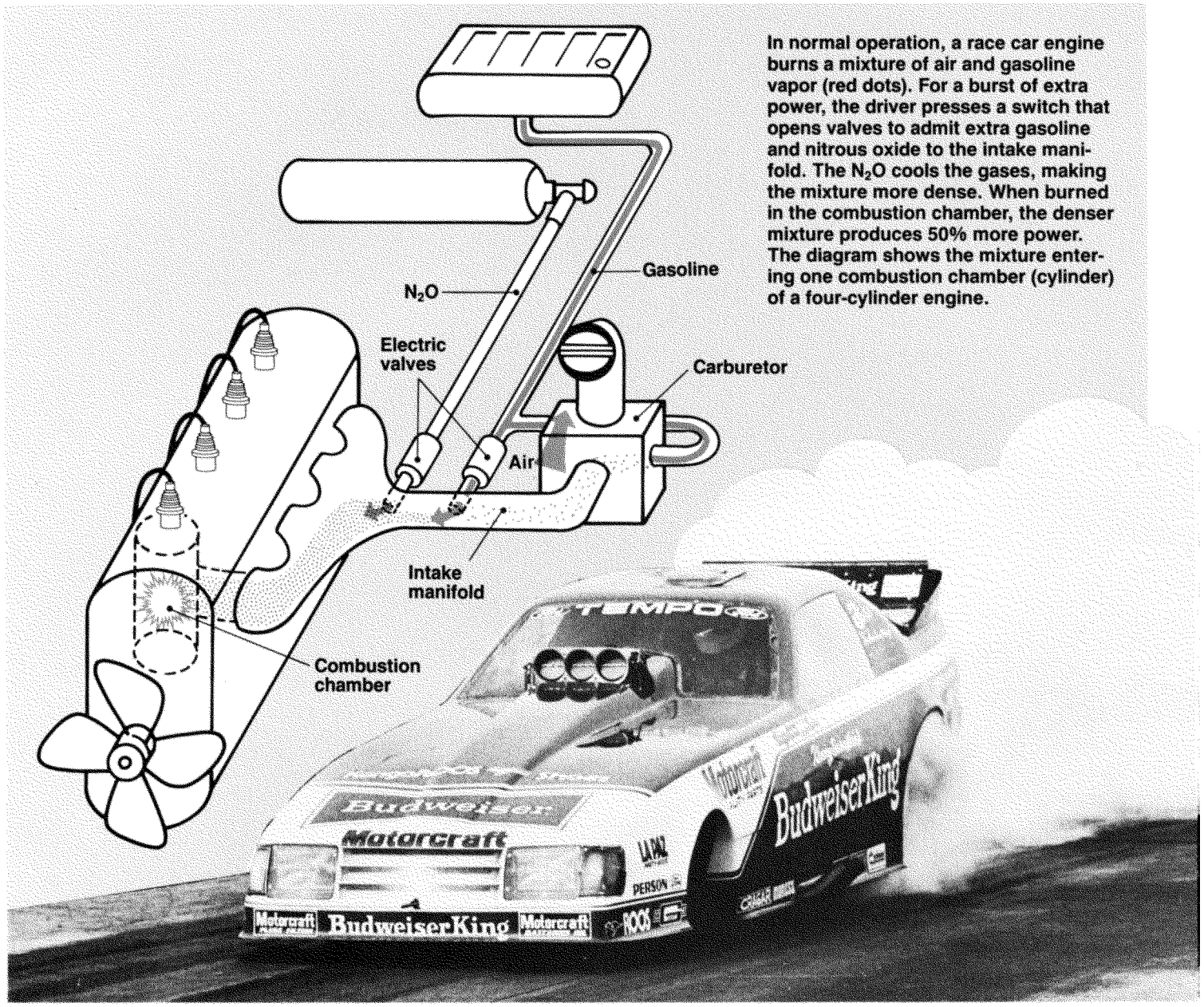
Not until 1844 did Horace Wells (1815–1848), a Hartford, Conn., dentist, temporarily fulfill Davy's prediction. Wells attended one of the many public entertainments that featured the inhalation of laughing gas by volunteers. Impressed by what he saw, Wells arranged to breathe the gas the next day immediately before a fellow dentist extracted a troublesome tooth. Wells felt no pain. He practiced the technique on a number of his patients and then in 1845 arranged a demonstration before his professional colleagues at the Massachusetts General Hospital in Boston. Alas, the demonstration failed, and Wells was denounced as a charlatan. However, present in Horace Wells's audience was William T. Morton (1819–1868), who the following year demonstrated the anesthetic use of *ether* at the same hospital. Ether soon became a standard anesthetic.

Horace Wells continued to campaign for his discovery but without success. He committed suicide in 1848. Nearly 20 years later, the effectiveness of nitrous oxide inhalation was conclusively demonstrated. Today, mixed with up to 40% oxygen and other gases, it is used routinely in dentistry and quite frequently during childbirth, sometimes in combination with other drugs administered by injection during childbirth. Nitrous oxide does not suppress all sensations like a general anesthetic but rather raises the pain threshold. Patients recover quickly and are left with a sweetness on the breath and a willingness, if not an eagerness, to return to the dentist's chair.

Nitrous oxide found few other uses. One of the strangest is its employment as a propellant in cans of whipped cream. Why does nitrous oxide find this odd use? In small doses it is harmless, and it is quite soluble in fats and lipids, the solubility increasing with increased pressure, according to Henry's law. When the pressure is temporarily released, the gas comes out of solution and froths the cream out of the aerosol can.

Nitrous oxide burns rubber

Recently, nitrous oxide has also found favor as a horsepower booster in hot rods and dragsters. The necessary equipment costs a minimum of $400, and nitrous oxide itself is by no means cheap. However, the horsepower boost is often spectacular, the races are short, and the prizes are substantial. How does the nitrous oxide work? In an internal combustion engine, a fuel (usually gasoline) is burned with an oxidizer (usually air). As the experiment with the wooden splint showed, nitrous oxide is, like the oxygen in air, a powerful sup-



In normal operation, a race car engine burns a mixture of air and gasoline vapor (red dots). For a burst of extra power, the driver presses a switch that opens valves to admit extra gasoline and nitrous oxide to the intake manifold. The N_2O cools the gases, making the mixture more dense. When burned in the combustion chamber, the denser mixture produces 50% more power. The diagram shows the mixture entering one combustion chamber (cylinder) of a four-cylinder engine.

porter of combustion. Unlike oxygen, its properties are such that it can be stored as a *liquid* under modest pressures in lightweight scubalike tanks. It is the injection of liquid nitrous oxide into the fuel–air mixture that makes its use so effective.

In a drag race, the driver pushes a button to kick in the nitrous oxide boost. Liquid N_2O passes from a tank in the trunk to the engine. Here it is injected as liquid droplets into the air–gasoline mixture in the intake manifold. At the same time, extra fuel is added to react with the extra oxidizer. The droplets of nitrous oxide vaporize, and in doing so, cool the gaseous mixture. Hence, by Charles's law, a denser charge with more air and fuel can be passed to the cylinders. On combustion, the denser charge produces more power and a temperature high enough to cause the nitrous oxide to react with the extra fuel. A sudden surge of power travels from the engine via the transmission to the rubber and the track. A nitrous oxide-powered car can change instantly from 400 to over 600 horsepower, provided, that is, the engine doesn't blow up.

What about the imprudent hot rodders, mentioned at the beginning of this article, who inhale N_2O instead of injecting it into their engines? They'll wish they hadn't. The company that supplies nitrous oxide to racers has announced that a small amount of sulfur dioxide, SO_2, is now being added to their product. This gives the gas a revolting smell and induces choking and nausea.

From a glowing splint and an aching tooth to whipped cream and an explosively fast dragster, at times science "moves in a mysterious way [its] wonders to perform."

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