



## The Nitrous Oxide Temperature and Pressure Relationship

The enthalpy of a gas/liquid is expressed as the thermodynamic product for a particular temperature/pressure. At normal room temperature (70F) and atmospheric pressure, nitrous oxide exists in a gaseous form, but when sufficiently compressed, it will transform to a liquid. Every gas has a different enthalpy.

Water (H<sub>2</sub>O) boils @ 212F at atmospheric pressure, yet when the pressure is raised to 28.8 psi, it will not boil until the temperature is raised to 248F. The critical temperatures for the following are:

- Water -- 705.2F
- Ammonia (NH<sub>3</sub>) -- 269.6F
- Carbon Dioxide (CO<sub>2</sub>) -- 87.7F

Raising temperatures to “critical,” changes each product to a gas phase. Nitrous oxide experiences the same phase change at critical temperature. This is why it is referred to as the “critical temperature.”

***In 1945 the NACA (National Advisory Committee for Aeronautics) which later became known as NASA, reported a critical temperature of 102F, and critical pressure of 1278 psi for nitrous oxide. Some researchers report a critical temperature of 97.7F and critical pressure of 1069 psi. The CRC “Handbook of Chemistry and Physics,” known the world over, indicates that the critical temperature is 97.6F and critical pressure 1072 psi.***

At 100F we would need 1100 psi, according to the enthalpy, and still not have 100% liquid. Our research has found that this can create a volatile situation with the critical state of nitrous oxide. At the “critical temperature” when phase change is occurring, a slight slow down in nitrous oxide rate can often be observed. The engine continues to make power but it starts to experience lean/rich conditions because of the mixture differences at phase change. Two phase flow (liquid/gas), at the critical point, is not a good thing. Two phase flow (liquid/gas) will always exhibit a slightly higher friction coefficient through the system. All liquid/gas two phase products (CO<sub>2</sub>, Nitrogen, Nitrous Oxide) at critical temperature and pressure often resemble a foam or micro-emulsion. This condition causes a slight increase in viscosity. In various phases of flow (plug flow, laminar flow, turbulent flow), these products act differently than when flowing as either a gas or a liquid. Research has been conducted in these areas in the U.S. and Canada for applications other than automotive.



Our conclusion is that 97.6F is the approximate point at which nitrous oxide starts its phase change and 102F is 100% gas. ***“Critical pressure” is the minimum pressure required to liquefy a gas up to its “critical temperature.” Our research has found that above 97.7F, nitrous oxide does not remain liquid. The world of science accepts the fact that: “The critical temperature is defined as that temperature above which a gas can no longer remain liquid, regardless of the pressure applied.”***

It is paramount that we hold this temperature down. Even after the nitrous oxide leaves the bottle and main line we have sufficient heat soak in our typical direct port nitrous plumbing to exceed 98F and normally have gas forming before leaving the nozzles. Fluid flow dynamics are always dependent upon mass density and pressure. As the Reynolds number or fluid velocity fluctuations occur during phase change, the result is a haphazard secondary motion known as fluid turbulence. These are very real issues that show up on the typical direct port system with massive amounts of plumbing and excessive volumes. From one system to another and from low power levels to a high power level, the nitrous oxide velocities experienced at critical phase can speed up and slow down. When measuring with a flow turbine (properly calibrated), this critical condition does not get picked up because it is simply measuring fluid regardless of how many bubbles are present, yet when the contents of the bottle are scientifically weighed, a small difference can be detected from a critical phase pull to a non-critical phase pull.

Conversely, we must not allow pressure to drop too low. At 70F we must keep pressure above 760 psi in order to maintain liquid. At 80F the pressure must remain above 865 psi. In cool climates with a large dose of nitrous oxide, this can be hard to do without bottle heaters. We must always be aware of the pressure/temperature relationship and never forget that “critical” means “critical” regardless of what you may have been taught.

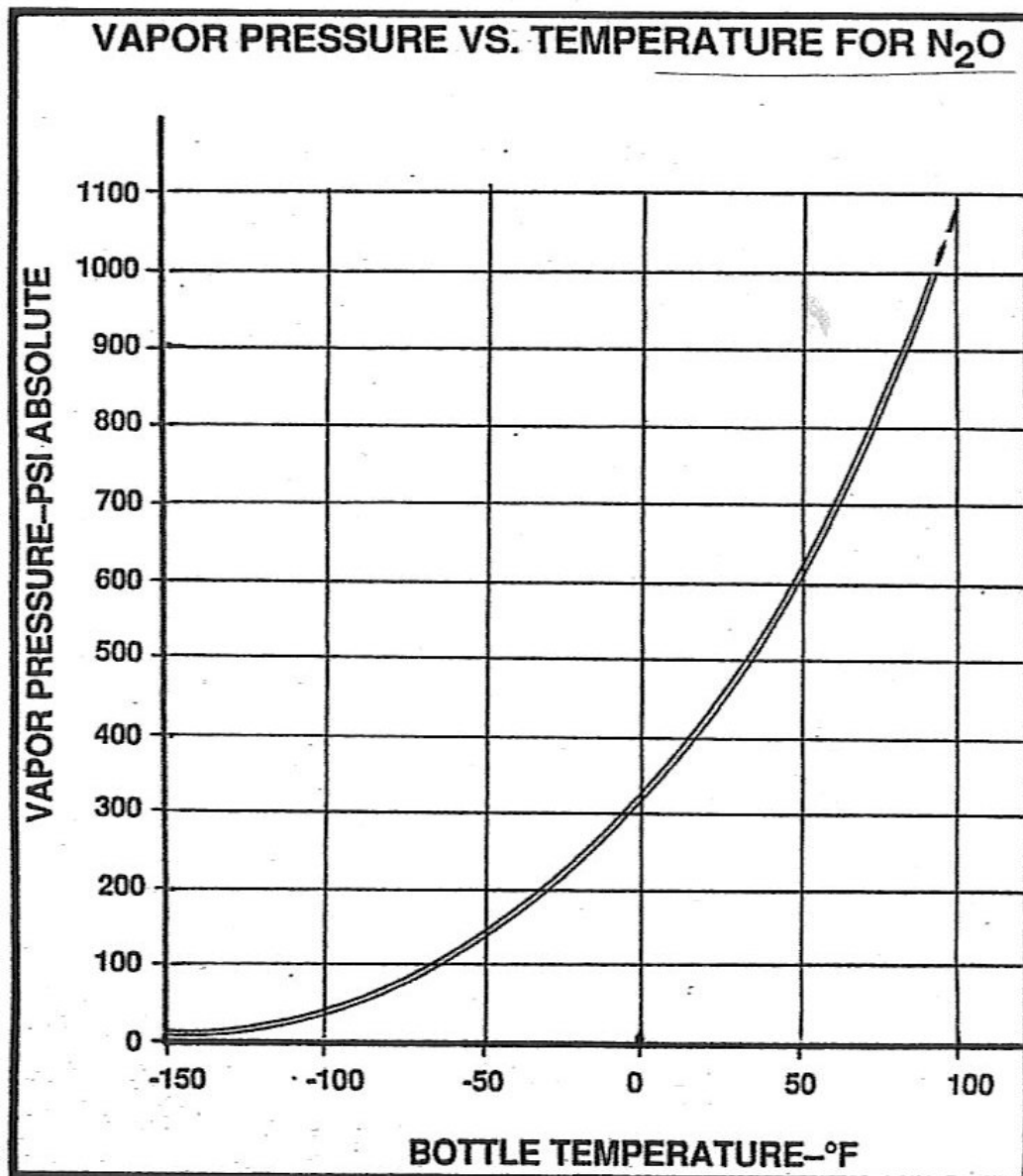
### **Nitrous Oxide (N2O) Physical Properties**

Molecular Weight	44
Critical Density	3.4 lb / US gal.
Critical Temperature	97.6-102F
Critical Pressure	1069-1278 psia
VP @ 68F	+/- 750
Boiling Point	-129F
Specific Volume @ 1 atm.	8.7c.f./lb.
Thermal Decomposition	565F
Oxygen Percent	36

## Nitrous Oxide Density of Liquid and Gas

Phase	Density (lb/ft <sup>3</sup> )	Temperature (F)
liquid	81.2	-129
liquid	39.1	86
gas	0.1146	70
gas	0.1172	59
gas	0.125	32

Note: The above densities and temperatures for nitrous oxide in a gas phase are at 1 atm.





As can be seen from the above data, nitrous oxide density increases as temperature decreases. From 86F down to -129F (a range of 215 degrees), we see that the density doubles. To put this into perspective, fresh water (H<sub>2</sub>O) has a density of 8.33 lbs/U.S.gal or 62.3 lbs/cf. For liquid nitrous oxide to be at the same density as water, the nitrous would need to be at a temperature well below zero. When heated, water turns to steam and we can easily see that a cubic foot of steam at a particular temperature and pressure would weigh a fraction of a cubic foot of liquid water. The same holds true for nitrous oxide.

Again, as we can see above, a cubic foot of nitrous oxide gas at 1 atmosphere is very light. With liquid under pressure and gas at 1 atm and both at 86F, we can observe a density difference of approximately 350:1. As we compress the gas with many hundreds of psi, the density increases tremendously to the “critical” point where it is about to turn liquid. At this point, the density is very near that of liquid. This is the state of nitrous oxide in many systems prior to exiting the jet. If our main lines from the bottles to the systems are short and have a minimum amount of plumbing, frictional losses are minimized and the nitrous stays very stable, but when the pressure at the jet is much lower than the pressure at the bottle we can have a critical state develop. The racer injecting 300 hp with a 15 foot dash 4 line, single bottle, long activation periods, and massive plumbing will experience a greater pressure loss at the jet (80-100 psi in some cases). The ProMod racer with short dash 6 lines, multiple high volume bottles, minimal plumbing, less activation time, etc, etc, may only lose half the pressure, but if pressure were low enough to begin with, may still be crucial if critical phase begins to develop. A very good way to monitor this would be to place a pressure transducer just prior to the jet on each cylinder and compare the pressure at the jet to the pressure at the bottle. When monitoring real time on the car, dyno, or flow bench, with all plumbing as it would be on the car, you will find a pressure differential in some cases that create “critical phase” nitrous. This situation is compounded with conventional fogger systems and massive amounts of plumbing between the solenoids and jet. As we introduce engine heat to the ferrous metal plumbing, this is again compounded. When the system is first activated, we not only experience a pressure loss, but a few seconds later the lines start to cool. They should only cool, but not frost. If we see frost on any manifold lines, we can be assured that the nitrous is indeed turning to a gas in our system. If the nitrous remains liquid, our manifold lines will resemble the main line and bottle, with no frost. If the nitrous oxide leaves the system in the desired form as a liquid and the temperature drop is low enough, we may see ice crystals form. If any amount of water is in the fuel, or if humidity is high enough, it can cause freezing within portions of the fluid.

Gaseous nitrous oxide creates a much hotter combustion chamber. Carbureted engines are in a slightly rich condition at the starting line without nitrous oxide. We then see a fuel lag when the nitrous oxide is activated, and with critical phase nitrous oxide conditions and multiple stages of nitrous, our fuel curve will go up and down many times during the run. This complicated situation is further hindered with declining bottle pressure. These conditions are not as problematic with EFI engines and when lambda or air/fuel is being



monitored on each cylinder. We have discovered that utilizing the “FAST” electronic fuel injection system and research by others with similar systems, a much flatter fuel curve and fewer lean/rich conditions occur, especially when nitrous oxide is going through phase change.

Many illustrate the need to have the nitrous injected over the fuel to develop a shearing effect and produce a more homogeneous mixture. They theorize the importance of the injection impinging upon the spray of fuel so that the nitrous and fuel mix better. Our research has found that it is far more important that each cylinder get the proper amount of fuel and nitrous regardless of the point of injection. In the case of electronic fuel injection, some inject the fuel in the common plenum area, some inject at the top of the runner, and some inject at the bottom of the runner. Very little if any difference is seen in fuel atomization, distribution, or power. In some cases of nitrous, fuel, or both being injected in the common plenum area over the top of the runner, more power has been observed. This is achieved by more effectively cooling the incoming air and creating a more dense mixture. This drastically super-cools and shrinks the outside air. Our largest concerns should be directed toward nitrous oxide “critical phase” and fuel lag. These two things combine to create a very volatile situation and a rich/lean mixture many times during a pass.