Nitrous Oxide

How Nitrous Oxide Systems Work

Source: www.grapeaperacing.com

Chemical Properties

A nitrous oxide molecule is made up of 2 atoms of nitrogen and 1 atom of oxygen. By weight it is 36% oxygen (air is only 23.6% oxygen). At 70° F it takes 760 psi of vapor pressure to hold nitrous in liquid form. The critical temperature is 97.7° F; at this temperature the vapor pressure can no longer hold the nitrous oxide in liquid form. At this point the nitrous turns gaseous and will be at 1069 psi. As temperature rises further, so will pressure, but it will remain in gaseous form. If you intend to siphon liquid nitrous, it is important to keep the temperature below 97.7°.

Normal bottle pressure will be around 800 psi, so when liquid nitrous is released, it will go from 800 psi to 14.7 psi (normal atmospheric pressure). It will then begin to boil and rapidly expand; the pressure drop will cause the temperature to decrease. Nitrous boils at 129.1° below zero, those kind temperatures can freeze skin in a fraction of a second, so take care when purging lines.

Combustion

Nitrous oxide is a non-flammable gas, it is an oxidizer. It provides more oxygen, so more fuel can be burned, and the result is more power. Alone, nitrous oxide will not burn, the enrichment fuel is where the added power comes from, and nitrous oxide allows that extra fuel to be burned.

The atoms in a nitrous oxide molecule are bonded together. The oxygen is not free, but fortunately the bond breaks down as temperature rises. At 565° F, the bond is broken and the oxygen is then free. Combustion temperatures are much more than 565°, so it's not a problem.

By adding nitrous oxide to an engine, the total amount of oxygen is increased and other gasses that do not support combustion (mostly nitrogen) are decreased. Nitrogen absorbs and helps carry heat away, when the total percentage of nitrous is reduced, temperatures rise. This speeds the burn rate and requires less timing advance for peak output. It is hard from many people to grasp gaining power with less timing, but it's a fact. Peak cylinder pressure must occur at approximately 20°ATDC to make peak power. If you speed the burn rate, peak cylinder pressure will occur too soon. It is easy to run too much ignition advance with nitrous, but too much will not only hurt power, it can quickly bring a nitrous engine into detonation and destroy it.

Detonation

Nitrous will increase the chance of detonation. To keep the engine out of detonation, you must control the extra heat that nitrous makes. The easiest way to do this is to add more fuel. All nitrous systems come with rich jetting to give you a safe starting point. The extra fuel takes away heat and raises the detonation limit. There is a limit, there will be a point where going richer will not help detonation and just reduce power output. IF that is the case, you will need to use other means to control detonation.

Another way of controlling heat is with water injection. A well set up water injection system will allow you to run the chemically correct nitrous to fuel ratio, so the system will be more fuel-efficient. If you don't try to over do it, and keep the hp levels within reason, running slightly richer should be all you'll need to control detonation. Water injection and running richer will both reduce the power output, but raising the detonation limit will allow more nitrous to be used to get more power.

Nitrous to Fuel Ratio

The chemically correct nitrous to gasoline ratio is 9.649:1, but that is too lean to run safely in most engines. The chemically correct air to gasoline ratio is 14.7:1, but at wide open throttle, we cannot run that lean without going lean. The problem is that every molecule of oxygen does not find and bond with every molecule of gasoline. The same goes for nitrous oxide; you need a richer mixture to better the chances of the nitrous mixing with fuel.

If a nitrous engine runs lean, it can destroy the engine in a matter of seconds. There must be enough fuel for the nitrous to react with, if there isn't, temperatures rise rapidly. The oxygen that couldn't react with fuel will oxidize any parts that get hot enough, and the next thing in line to burn is aluminum, so don't run lean.

Cooling Effects

Cooler intake air is denser and contains more oxygen atoms per cubic foot. So cooler air will allow more fuel to be burned and intern make more power. A 10-degree drop in temperature can add 1 to 1.5% power to an engine.

Nitrous oxide boils at -129°F and it will begin to boil as soon as it is injected. This can cause a 80° or so drop in manifold air temperature. Now if we are dealing with say a 400 hp engine, we can see well over 30 hp gained from the cooling effect alone. This cooling effect also helps the engine deal with detonation.

Plate Systems

The most common systems are the spray bar type. A plate gets sandwiched between the carburetor and intake manifold. There are two spray bars in each plate, the upper one is nitrous oxide and the lower one is fuel. The nitrous sprays over the fuel to give a better nitrous fuel mixture. Plates are easy to install and provide good performance, but they are not the best. The nitrous must travel through the entire intake manifold. The longer it takes to get to the cylinders, the more it expands. The more room that nitrous occupies, the less of the normally aspirated mixture the engine will get. So the engine will make more power if the point of injection is as close to the cylinders as possible.

Another problem with spray bars is when using larger kits; the motor will hesitate slightly when the nitrous is activated. When the nitrous first travels down the spray bar, it hits the dead end of the bar and sends a pulse backwards, which impedes flow. Once the system is running there are no problems, but that slight hesitation could cause tire spin. This reversion is mostly a problem on larger kits, around 300 hp or more.

Nozzle Systems

Also known as foggers (started by NOS Systems), the nozzle nitrous systems can produce much more power without any reversion problems. With this type of system, you must drill and tap each intake runner near the cylinder head and run at least 1 nozzle for each cylinder (many multiple stage systems will run more than 1 nozzle per cylinder).

There is much more plumbing in a nozzle system, but they give better mixture (or fog), because the nitrous and fuel mix before they are injected. The high pressure nitrous breaks the fuel into a very fine mist.

The point of injection can be very close to the cylinder for minimal expansion. In many cases, depending on how the nozzles are situated and aimed, the normally aspirated airflow can increase. So there are many advantages to the nozzle systems.

Other than the extra plumbing, cost is a downfall of nozzle systems. They are significantly more expensive than plate systems.

If you car is traction limited, a plate system may be a better choice. Nozzle systems tend to have a harder hit than plate systems. The hit can be somewhat controlled by the length of the line form the solenoid to the jets however. A longer line will soften the hit by allowing more time for the nitrous to expand initially. Line length is a good tuning aid to get the best launch.

There are new types of nozzles systems out now that fit under the fuel injectors on many OEM engines. I have no experience with them, but the idea looks good. Most of these type systems are dry flow systems than inject nitrous only. They override the ECM when the nitrous system is activated to use the fuel injectors to provide enrichment fuel.

Those type systems are limited to how much extra fuel the injectors can flow. If more power is desired, larger injectors may be required, which could hurt idle quality.

Average Power

If you were to build a normally aspirated 550 hp 350 Chevy, it would have to rev to 7000+ rpm to make that kind of power and only make that power in a narrow rpm range. A nitrous injected 350 Chevy making 550 hp would make that power at a much lower rpm and give higher average horsepower. So the nitrous engine will out perform the normally aspirated engine by a healthy margin. The reason is that nitrous flow remains constant no matter what rpm the engine is at. At lower speeds there is more time for the nitrous to fill the cylinders, so you get more nitrous in the cylinders per power stroke at lower rpm. This will boost power more at low rpm (before the engine is in it's power band).

As rpm increases, and gets in the power band of the engine, you will get less nitrous per power stroke, but the engine will start making more normally aspirated power. This really flattens out the torque curve and widens the power band. When it comes to racing, peak hp is pretty much meaning less. What is most important it how much average power the engine has in the rpm range used to race. High peak numbers don’t mean much if the engine is only in that range at the top of every gear.

So Why Not Pure Oxygen?

Air has only 23.6% oxygen by weight, the rest is made up largely of nitrogen. That nitrogen does not aid in combustion at all, but it does absorb and carry heat away.

When you add nitrous, it has 36% oxygen with the rest being nitrogen. So the more nitrous oxide you add, the less total percentage of nitrogen is available to absorb heat there is. That is why nitrous increases engine heat very rapidly.

If we were to add pure oxygen (which has been tried), the percentage of nitrogen would fall much faster as more oxygen was added. We would not be able to add much oxygen before heat was a major problem to control.

Also compressed oxygen is in a gaseous form, so adding oxygen takes up more room and reduces normally aspirated power, and the amount of nitrogen from it. By injecting liquid nitrous, the normally aspirated power only drops slightly and it is adding oxygen and nitrogen. To put it simply, with nitrous oxide, we can get more oxygen atoms in the engine and have a lot more nitrogen as well. Nitrous can make much more power before heat is uncontrollable.

Source: www.grapeaperacing.com

Camshafts For Nitrous

Choosing a Camshaft

Optimum valve timing for a nitrous injected engine will be different than optimum timing for that same engine normally aspirated, so you will have to make a choice as to whether you want the most power with or without nitrous. Obviously if you are driving the car on the street most of the time, you will want the best power off the bottle. If you find that you can spare some power to make your car faster at the track, picking a camshaft to favor nitrous can make a substantial difference when nitrous is in use. Of course it is a trade off, but usually the power that you make on the bottle, will be far greater than the amount lost off the bottle.

Pumping Losses

Nitrous oxide adds oxygen, much of which is in liquid form. So you can see that a large intake valve and port is not required or desirable. Larger intake ports cause more of the nitrous to turn to a gas and reduce the amount of normally aspirated power, if the nitrous takes up more room, there will be less room for normal aspiration, reducing volumetric efficiency.

Also, you do not want or need longer intake duration or a higher lift, so the intake side of the cam does not need to be any different when nitrous is used. Getting air in is no longer the main concern when injecting nitrous.

The exhaust is a totally different story. All that extra oxygen and fuel makes for a substantial increase in exhaust volume. How can the exhaust valves deal with this? They can't, pumping losses go out of sight. Much of the extra power made in the cylinders never makes it to the flywheel, because it is used to push out the exhaust.

Since making the exhaust valve large enough and the ports flow enough is impractical with most cylinder heads, we must take other actions to cut pumping losses.

Cutting Pumping Losses

The first obvious step is to use a dual pattern cam with longer exhaust duration. Opening the valve earlier will help by getting the valve open more and bleeding off some pressure before the piston starts moving up the bore. Reducing pressure in the cylinders when the pistons are passing BDC means less resistance for the pistons on the way up. This does eat into the power stroke, but more power is freed up than would be made by holding it closed longer. A better solution would be a larger exhaust valve and better port that allows more low lift flow, but that is not practical for most heads. Designing such a head would definitely help power on the bottle, but also trade off power off the bottle.

The blow down phase (overlap period) becomes very important in a nitrous engine, because the gasses have much greater velocity and can over scavenge, closing the valve exhaust valve a little earlier helps.

Anytime you make more power by reducing pumping losses, you are freeing up horsepower that already existed in the cylinders. The engine will still experience the same loads, but more power will be put to the flywheel and less will be used to push out exhaust.

Camshaft Specifications

As I said earlier, the intake needs to remain pretty much the same, but the exhaust needs more duration, an earlier opening point and an earlier closing point. To make this happen, you need to use a dual pattern cam with more exhaust timing, and a wider lobe separation angle. Cam's with 112-116° lobe separations are common in nitrous engines.

To keep the intake timing the same, you must install the cam advanced, usually 6-8° advanced. The good things about this are that advancing a cam will bring more low-end (at a trade off of top-end) when running without the nitrous and the wider lobe center angle will also help idle and increase vacuum. Even the most radical nitrous profiles are usually pretty tame on the street. Ultra high lift cams are not needed to make power with nitrous. On the exhaust side, the low lift flow is the most important thing, and must be dealt with much more seriously than high lift flow.

Cylinder Head Modifications for Nitrous

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Intake to Exhaust Flow Ratio

For a normally aspirated engine the exhaust flow needs to equal to about 75% of the intake flow. When nitrous enters the equation, the exhaust needs to flow more. How much more depends on how much nitrous you're planning on using. As a general rule of thumb, the exhaust flow needs to be increased about 5% for every 20% increase of power from nitrous injection. In other words, if 40% of your engines power is made from nitrous, the exhaust flow needs to be equal to about 85% of the intake flow. This is of course limited to how much the head can be modified.

Intake Port Work

Nitrous adds so much oxygen that getting oxygen in is no longer a problem. A large intake port is not needed. The larger the port, the more surface area it has and the intake charge will have lower velocity. Slower moving nitrous will have more time to turn from a liquid to a gas, so a large port will have less liquid nitrous getting in the cylinder.

As nitrous turns to a gas it will expand, taking up room in the intake and reducing the amount of normally aspirated air. More surface area will give the nitrous more area to absorb heat, which will cause even more nitrous to turn in gas. The same goes for large intake valves. The intake valve is the hottest part of the intake system and when nitrous is involved you don't want excess surface area on the valve.

For small-block Chevy engines, a 1.94" intake valve is more than large enough for even all out 500+ hp nitrous engines. The exhaust is a different story.

Exhaust Port Work

All the extra exhaust volume has to be dealt with. The exhaust valves of a nitrous engine are almost always too small. When possible it is best to reduce the size of the intake to allow room for a bigger exhaust valve. A 1.94" / 1.5" Chevy head is a good starting point. 1.6 valves can be installed with no problems and even 1.65" are possible.

The head of the exhaust valve should not have any sharp edges. It should have a nice smooth radius to allow the exhaust to travel around it as easily as possible. The valve job on the exhaust is the most important part, there will be so much more cylinder pressure when the exhaust valve opens which makes for a lot more gasses trying to escape through the valve at low lifts. Low lift exhaust flow should be your number one concern (up to about .300" lift). A good multi angle valve job is the best bang for the buck in a nitrous engine.

The short side radius will usually benefit from a straight cut to the port floor. The area directly past the seat should be as wide as possible. The valve seats should be slightly wider also (.010"-.015") to help get rid of some of the extra heat in the valves that nitrous will make.

Combustion Chamber Modifications

Usually you cannot do much chamber work without reducing compression and being forced to use a high dome that hurts power. With nitrous, a high compression ratio is not needed, so some work can be done in this area. Nitrous can make some very respectable power figures with a compression ratio in the 10:1 area.

First step is to unshroud the exhaust valve as much as possible so the gasses can move around the valve easily. The next step is to polish the combustion chamber and remove any sharp edges. Sharp edges will be the first to get hot and cause detonation (as well as be the first to melt). Polishing the combustion chamber will help keep carbon build up to a minimum (a good idea for any engine).

Rocker Arm Studs

One area that is often overlooked are the rocker studs. The intake does not get any extra loads from nitrous oxide, but the exhaust studs will get much more abuse. There is much more cylinder pressure when nitrous is being used, so the exhaust valve will have to open against a great deal more pressure.

It is not uncommon for rocker studs to break in nitrous engines, because most engine builders do not realize the extra loadings on them. Always use a quality exhaust rocker stud and where possible, use a larger diameter stud.