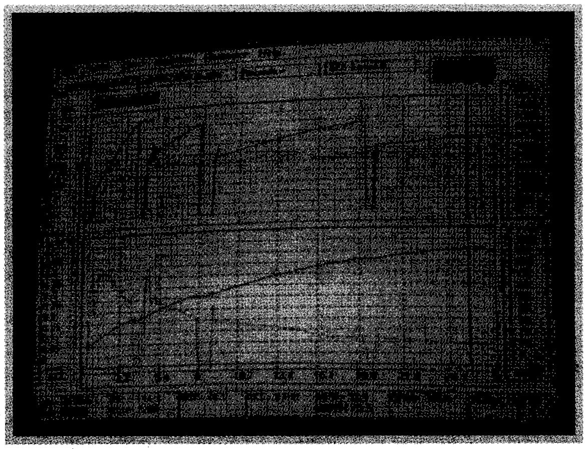
REAL WORLD DYNO



DYNO AND WIND-TUNNEL TESTING FOR THE SERIOUS ENTHUSIAST

BY DAVID VIZARD

"If it can be measured, it can be improved." The accuracy of this statement is borne out by the fact that to extract horsepower from an engine, consistent with current state of the art, requires the use of a dyno. Extracting additional power from a well-developed engine is almost always the summation of a large number of small increases, rather than the other way around. Without a dyno it's not easy to tell which way your last engine change took you - better or worse. It doesn't take much thought to appreciate the positive assets of owning a dyno. Unfortunately, even the least expensive dynos are beyond the means of most serious enthusiasts.

Hal Middleton, of DynoLab in Seattle, has gone a long way toward setting this straight with his STR 2020 on-board dyno. For those unfamiliar with the term, an on-board dyno is one that installs on the vehicle, rather than the vehicle or engine being installed on it. However, DynoLab's $1500 answer to cost-effective dyno testing isn't just about being able to dyno test for less money. The on-board dyno not only provides "installed" power figures, it also doubles up as a means of duplicating the results of a $500,000 wind tunnel. This gives the user the ability to assign real-world values not only to aerodynamic drag, but power figures that take into account changes that can occur to the engine or chassis while in use.

Function

The DynoLab unit's mode of function is relatively straight forward. It determines horsepower from four interrelated functions, namely speed, acceleration, mass, and drag. By knowing the value of these factors at any moment in time, horsepower can be computed. The basic formula looks like this:

$$\frac{(\text{lbs Mass} \times \text{Acceleration in G's}) + \text{lbs Drag}) \times \text{Speed in mph}}{375}$$

While the concept of measuring horsepower by means of an accelerometer is not new, this patented on-board dyno utilizes methods and techniques that allow it to greatly outperform previous attempts. Its refined design gives it the ability to produce commercial, rather than hobby quality, results. Most of the commonly available inertia dynos, as they are known in engineering circles, are of the double integrating type. This means they use the measured acceleration to compute speed (first integral of acceleration) and distance (second integral of acceleration). Since the calculation of horsepower requires speed as one of its inputs, any error produced in the speed calculation becomes compounded in obtaining the final result. Although such a system is workable, tests must be on level ground and the unit requires a much greater degree of finesse to produce realistic results than the less convenient, but intrinsically more accurate route that DynoLab choose to go. By contrast, the DynoLab unit does not require the road to be perfectly flat. With the DynoLab unit, speed is input either directly from the vehicle's speedo or, for a race car, from a speed sensor located on the prop shaft.

With an accurate speed input taken care of, the next input to concern ourselves with is the acceleration and drag. Both these aspects are dealt with by an accurate aerospace-grade accelerometer. Drag is dealt with differently than acceleration due to its more complex nature. Overall vehicle drag is composed of two distinctly differing forms of drag, one rolling, the other aerodynamic. From an input of the vehicle's weight and by performing two calibration coast-down runs, one at low and one at high speed, the DynoLab STR 2020 internally generates a mathematical formula allowing it to compute, on the fly, total vehicle drag.

Having been confronted with on-board units built along similar lines, and which all things considered, did a commendable job, our first concern was to question the accuracy of the STR 2020. The principle of operation was sound, but obviously could be no better than the hardware used to make the relevant measurements. In testing this unit we made the assessment of its accuracy a priority, but before getting to that, let's look at the installation procedure.

Installation and Calibration

For testing, the sample unit was installed in our race-car tow truck. The first step was to install the accelerometer in an area free from engine or road-induced vibrations. A position directly under the seat was determined best and removing the seat, cutting the carpet, and drilling the appropriate holes proved the longest part of the installation.

With the accelerometer in place attention was turned to speed measurement. The STR 2020 is designed to use the OE speed transducer as used on most late model vehicles. For our '90 truck, coupling up the speed sensing side only involved making the appropriate electrical connection. What was now left to do was little more than a question of routing the wiring so no one fell over it on the way in or out of the truck. When all was done, it appeared we had spent more time taking photos than installing the STR 2020.

With the installation done, calibration came next. The first step was to zero out the accelerometer. This involved finding a flat surface on which to park the truck, marking the position each wheel occupied. Next, using the digital readout, the accelerometer was rotated in its mounting until a zero reading was seen. Then the truck was turned around and positioned on the same spot and half the difference shown on the readout was backed off by re-adjusting the accelerometer. It was during this exercise the sensitivity of the accelerometer became evident as we found it would register one thousandth of a G with apparent ease.

With the installation complete it was time to go through the calibration procedure. This involved nothing complex and was just a question of following the manual's clearly written instructions. As per these instructions we weighed the truck and did speed and coast-down calibrations. From the time we commenced installation to doing our first test run was some five hours, including our photos, so installation is by no means lengthy.

Test Time

To increase the steepness of our learning curve, Hal Middleton volunteered to demonstrate the STR 2020's capability not only as a stand-alone unit, but also how it performed as a data acquisition unit when used in conjunction with a laptop computer. Part of the equipment supplied with the STR 2020 is a program written by physicist, Dr. Clint Kenner. By dumping the output into the laptop we could later, at our leisure, view, analyze, dissect, and manipulate stored data. We made a few runs to get the hang of things and came up with some useful observations. The most important of these is that testing should only be done in still or near-still conditions. A wind, especially a blustery one, will skew the results. This is a consequence of having very sensitive equipment. Although a car will be far less susceptible, our test truck's heavy duty suspension was rigid enough to transmit road shocks to the accelerometer. There is a filter circuit built into the unit which goes a long way to compensating for this and we have heard that sprint cars are managing to get workable results, even on dirt tracks. So that we could maintain a high degree of sensitivity, we made a point of only testing on smooth roads, rather than increase the signal filtering.

Number Crunching

After about two dozen runs through the gears, we took the laptop's stored data and dumped it into a regular 486 PC computer. The ability to analyze and manipulate the data made a powerful tool that any technically proficient racer could put to good use. Some of the nearby photos show the work sheets that come up on the screens. From this data we were able to not only get horsepower, but also figures on torque, speed, distance, and time. Fig. 1 shows a typical printout of third gear engine output. From this graph we took the power and torque data, and with a few clicks of the mouse, produced Fig. 2. It was interesting enough to get the basic horsepower and torque data, but to be able to determine such things as time to speed, 0-to-60 ft. and 1/4- mile times, rpm shift points, launch G's, vehicle drag co-efficient, plus a number of other useful factors, was really exciting.

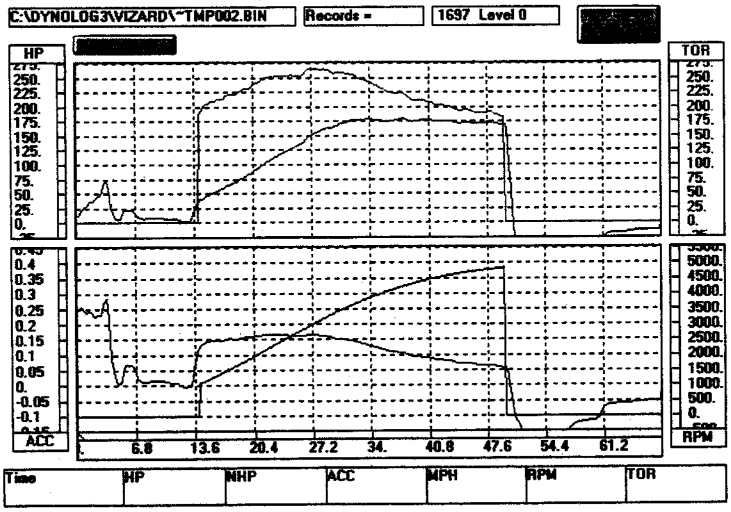


Fig. 1 — This graph shows the acquired data from a third-gear test. The top curve in the upper graph is torque and the lower one horsepower. In the lower graph the curve arcing from low to high is the rpm and the other is acceleration in G's.

One aspect the STR 2020 revealed that is difficult to duplicate on any other sort of dyno is the effect that accelerating through the gears has on available flywheel power. Although the power developed in the cylinders varies little from one gear to the next, what happens to it from there on considerably changes the final result. Because the engine accelerates faster in low gear, more of the cylinder- developed power goes into accelerating the mass of the engine's internals and the flywheel assembly. The lower the gear the more this effect reduces the power available at the flywheel.

Intriguing though all this was, we were initially faced with a little problem. Our truck, when put through its paces on the quarter mile, consistently returned performances better than published test figures, so we knew it to be up to scratch. However, according to official Chevrolet sources, our truck was supposed to produce some 200 SAE HP, but the STR 2020 indicated the motor had only around 185. Was the STR 2020 misleading us or —— ? By way of a provisional check, a call was made to Ward Spoonmore, one of Edelbrock's top electronic whiz kids. During the course of his work on vehicle computer programs, Ward gets to see the results of many fully dressed, stock-motor dyno tests. We told him our motor was indicating 185 corrected HP and asked how far off this might be. His answer was, quote, "Heck, that's right were a good one is." Ward's expert opinion further boosted our confidence in the STR 2020's data gathering capability, and so encouraged, we decided to put it through its paces by doing some real, live, product testing.

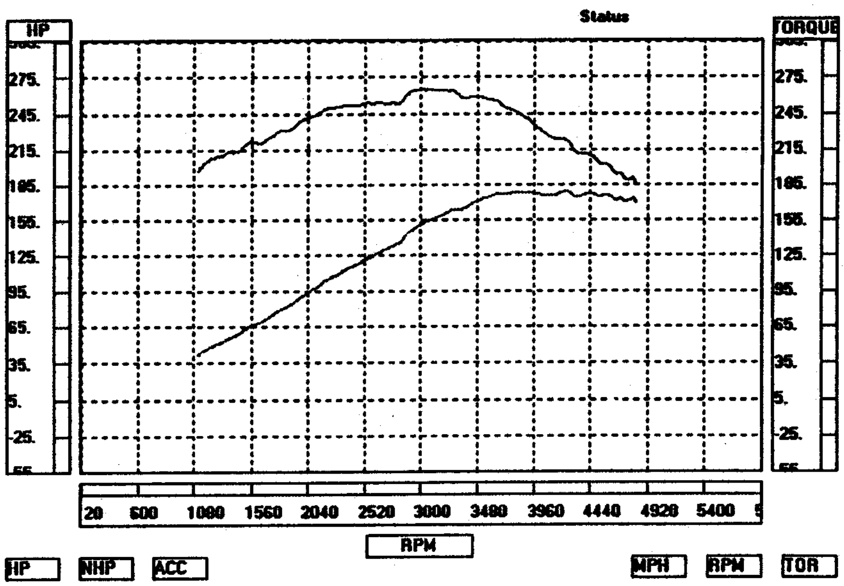


Fig. 2 — Using data from that shown in Fig. 1 we had the STR 2020 software produce this power/torque curve. A couple of mouse clicks was all that was required.

Exhaust System Test

The exhaust system on catalytic-converter-equipped GM trucks has a flow capability best described as one step removed from a cork in a Champaign bottle. Knowing this, it seemed like a good idea to do something about it. A call was made to Walker's John Brubaker, who sent us one of their high-flow, honeycomb, monolithic converters to replace the stock GM pellet converter. This flowed some 404cfm (at 25 inches H^2O) as opposed to an "as-new" stock converter at 210cfm. Along with this, an Edlebrock RPM muffler, which at some 550cfm turned in higher figures than some race mufflers we have tested, was installed. With no changes to the vehicle computer, our STR 2020 produced the before and after results as per Fig. 3. After these results were in we called Edelbrock's head of exhaust R & D, Bill Stieskel, and asked what kind of power increase we could expect from this combination. Bill reported that an 8-to-10 horsepower increase was typical for a truck like ours. The STR 2020 showed a 9.3 horsepower increase as per Fig. 3. In addition to the extra power the exhaust system gave, our freeway mileage testing indicated a small improvement of about 0.2 mpg in fuel economy. Finally, while remaining far from a high-dB cop hailer, the Edelbrock muffler made our truck sound like the sport truck it's supposed to be.

CD Test

The STR 2020's ability to do the job of a $15,000 dyno now appeared to be established beyond reasonable doubt. This left us wondering how it would fair as a stand in for a regular $500,000 wind tunnel. By entering the truck's frontal area into the "Car Profile" screen, the computer calculated it had a coefficient of drag of 0.432. All things considered, that seems a very commendable figure. To make use of this info, and to see if it could be improved, we called upon the assistance of Dave Mihelich at Fuller Camper in Riverside. We discovered Dave appeared to know camper shells like Garlits knows drag racing. We asked Dave if he knew of any camper shell that would significantly cut aerodynamic drag. He told us there were a couple that he felt significantly cut drag. These observations were based on personal experience, plus feedback from customers who had found measurable mileage gains. His choice as one of the best was produced by SnugTop. We contacted SnugTop and arranged for a camper shell to test. Doing the aerodynamic tests were simple, as it only involved performing another set of coast-down tests. Doing the freeway fuel-mileage testing to determine the effect of any drag changes took a little longer. However, the results were well worth the effort. This beautifully made, top-of-the-line camper shell, with its near-flush-fitting windows and thoughtfully curved surfaces, cut the drag coefficient from 0.432 to 0.403, a reduction of no less than 7%. This resulted in a mileage increase from 20.12 to 20.99 for a 0.87 mile per gallon or 4.3% improvement. In addition to mileage and performance improvements, the SnugTop shell cut high-speed wind noise noticeably and its good looks constantly bring forth complimentary comments.

Tire Performance Test

Although we've done many more tests, the last one we will discuss in this article concerns tires. About a year ago Michelin tires caused something of a stir by announcing they had developed new technology which allowed them to make significant reductions in rolling resistance and increases in tire life, while enhancing grip, handling, and ride quality to performance car levels. Their first tire, the MVX4 was designed as OE for the new Mercedes S-class and BMW Series-three sedans. Both these companies can be considered discerning customers and this prompted a hard look at what Michelin was doing. The result of our further investigation was the acquisition of a set of test tires. These, at the time, were only available in 16 inch as opposed to the stock 15-inch size. To fit the new

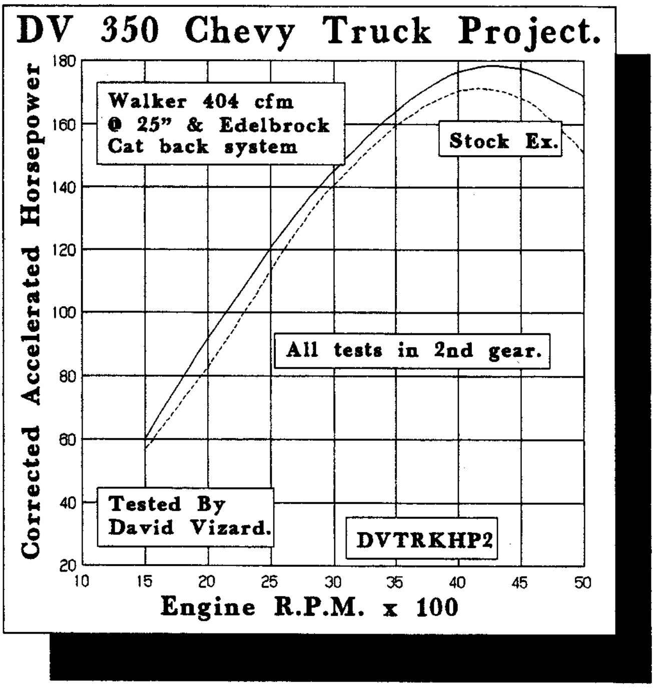


Fig. 3 — Adding a high-flow Walker catalytic converter and Edelbrock stainless exhaust system produced these before and after figures. The almost 10 horsepower increase came with a mellow, sporty exhaust note at near-stock noise levels.

The display unit was positioned directly in the driver's line of view for easy reading.

Michelins to our '90 Chevy truck, Progressive Wheels of Riverside helped us out with a set of their good looking aluminum wheels which shaved off over 50 lbs of unsprung weight. When put to the test, the STR 2020 revealed that the Michelin MVX4's cut the rolling resistance from 8 lbs (per thousand lbs of vehicle weight) to something between 4 and 5 lbs per thousand. Usually long life is achieved by the use of harder tire compounds which normally have less grip. This was not the case for the Michelins. At speed they were quieter then the OE Kelly Springfield tires and provided far better grip. Our best launches on the stock tires produced a maximum of 0.55G at our test site. The Michelins upped the anti to 0.64 G, an increase of over 16%. The STR 2020 also showed the 60 ft. time dropped from typically 2.67 seconds to 2.38 seconds and the 1/4 mile times came down by an average of some three tenths.

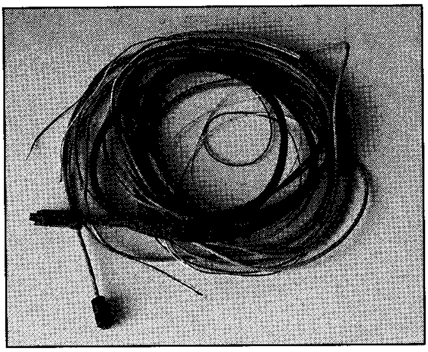
Accuracy Tests

Repeatability and sensitivity were two factors we went to some lengths to test. To satisfy ourselves as to the effectiveness of the STR 2020, we devised some simple tests to check its ability to produce consistent results. Using the same test site, and making sure all tests were done in still air, we tested the truck under identical load conditions, but varying weather conditions, several weeks apart. On each occasion the coast-down calibrations were re-run to cancel the effect changing air density has on drag. Using our B&G weather station to correct observed horsepower figures, we found that 92% of our results repeated closer than 3%. Subsequent chassis dyno tests on a highly repeatable (better than 0.7% in our experience) 1200 hp DynoJet chassis dyno indicated that the limit of our truck motor's "output repeatability" was no better than this. As a result, all we can say here is that if testing is done with due attention to the variables that affect it, the STR 2020 can produce accurate repeatability.

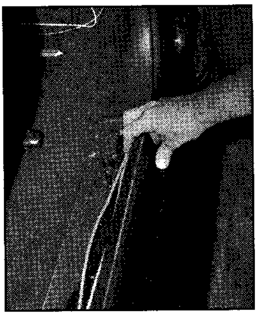
One other test we did on several occasions was to test sensitivity. For this we would run a test, then without telling the computer, add a small amount of additional weight to the test vehicle. A re-run of the test over the same piece of road would then be done. A playback of the data should reveal a small reduction in power. By knowing the weight that was added we could compute the difference we should see between the curves with and without the extra weight. Under closely controlled test conditions the STR 2020 proved capable of consistently detecting as little as a two horsepower change in over 180 horsepower.

So who has put their faith in the STR 2020? We know of some Pro Stock teams that, after a demonstration, are about to install it. Also in Winston Cup we have King Racing (#26 Quaker State car), Petty Enterprises, Madcap Racing, and for some corporate names try Bob Gore, former chairman of the board of Cosworth, General Motors, Mack Trucks, and AMOCO.

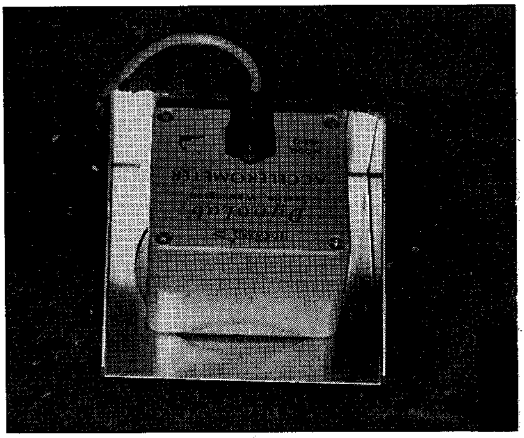
Our conclusions are that the STR 2020 is a useful tool to any serious drag, road, or circle track racer.



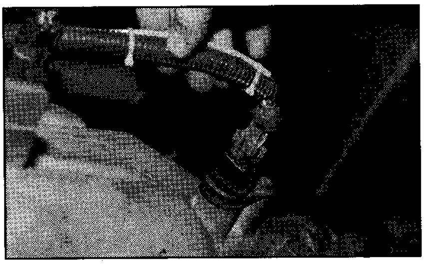
All the essential wiring was in the form of a "plug-in" wiring loom which made for a fast and simple turn-around on this job.



Where possible, all the wiring was hidden under the carpet or behind panels to make a neat job of the installation.



The sensitive accelerometer was positioned under the seat and secured to the body/frame to reduce the possibility of picking up unwanted body panel resonance.



The STR 2020's speed measurement system used the OE speed transducer so making the connections became little more than a plug-in deal.

"Doc" LeClaire and DynoLab's Hal Middleton prepare to make a test run with the STR 2020 making use of a laptop computer for data storage.