SUNSET ENGINE DEVELOPMENT

I have always considered the substitution of the internal combustion engine for the horse marked a very gloomy milestone in the progress of mankind. - Winston Churchill

WEIRD SCIENCE

I've recently read two interesting books. Again they are about quantum physics. The first one is called *THE GOD PARTICLE* by Leon Lederman. I'd be lucky if I understood 2% of the book but nonetheless I got a lot out of it. Not about particle physics but about the nature of experiment and the peculiarities of science. He discusses theories and the testing of them. Things he said about theory, experiment, testing, data and observation have made me feel better about our business of testing engines and interpreting data. I would like to pass some of this on.

We may lack the physicist intellectual prowess, and while our job isn't as respected as his, I can see many similarities between what he does and what we do. He uses instruments to gather information (data). He must interpret this information and in doing so this raises many more questions and quite often frustrations. Engine dynamometery is a quintessential example of a basic science not wholly unlike what real scientists do. To me the book seemed filled with great examples of analogies between the development of the IC engine and the problems physicists face in the quest for the ultimate particle.

Technically of course our profession is pint-sized compared with that of astro or quantum physics. What we learn has no sociological benefit, therefore, the rest of the world doesn't care about it. The scientists' instruments are vastly more complex and expensive than ours but he has the same problems as we when it comes to gathering, interpreting, believing and applying his data. I particularly enjoyed his descriptions of what he calls **"The eternal love-hate relation between theory and experiment."** The book has many examples of this quandary. The nice thing about it for us is that we don't have to take ourselves very seriously since there is little chance of race engine technology contributing to the advancement of our culture.

In science and more specifically in physics scientists are continually throwing out theories as fresh data constructs new ones. "**The interaction of theory and experiment is one of the joys of particle physics"** (Lederman). It is also the main motivation for us to dyno every day possible. As we test new theories and parts on the dyno we continue to make observations and compare them against theories. Most observations create more questions than they answer (more on this later). Although rare, sometimes we actually perceive that we may have learned something. It is a thrill to learn things that very few other people know and it is particularly satisfying when what we learn results in a horsepower gain. **"Sometimes something completely unexpected and**

bizarre happens which bring theories under suspicion." (Lederman). If subsequent observations show that it was right after all, we rejoice and have an olive. **"Discoveries are always quasi-sexual experiences"** (Lederman).

When I speak of disproving theories, I don't mean disproving physics. I mean disproving things that are commonly practiced and considered the "way to do it" by magazine articles and other engine builders. There is nothing is more rewarding than disproving a myth, popular theory or practice.

The particle accelerator is to the physicist as the dyno is to the engine builder. It's the tool by which each prospective nerd investigates the mysteries of his science. There are different types of accelerators just like there are different types of dynamometers. Physicists have continued to update their accelerators as technology advances and dyno facilities are doing the same. In each field ("discipline" as Lederman calls it) some labs that are ahead in one area may be behind in another.

To get on with this story I'd like to talk about how we do not often believe what we see and that we are often victims of our education. Take the case of my turbocharged Ford project. I had Sonny Bryant build a billet crank and when it came I noticed it was not cross-drilled. This bothered me because this engine has to be perfect - we are not allowed any mistakes. I finally called Sonny and asked him why no holes. He couldn't give me a reason. He only said that when he cross-drilled Glidden's cranks "he drove over the rods in the lights." I was still bothered because I figured he wasn't being told the whole story. I discussed this problem with John Callies at the engine conference that winter (two years ago now). On his recommendation I sent him the crank to see if he could put one of his crankshaft oiling systems in it - but he couldn't. Lost sleep or not I had to use it.

Ever notice that about the time you think you're to graduate from the school of experience, somebody thinks up a new course? Somewhere during the development of the Trans-Am engines we suddenly started having bearing problems. When something totally unexpected like this happens you look at and suspect everything. Along about this time Callies quit cross-drilling their cranks (John Callies also left Callies Performance). We had both types; one in each Trans-Am engine. During this bearing problem (I'll relate this interesting problem at another time) the non-cross-drilled crank seemed to be far better than the drilled one. What gives? Callies said their research showed that after about 3500 rpm the oil did not go past the center of the main due to centrifugal force. This force held the oil close to the OD of the cross-drill. To compensate, they delete the cross-drill and drill a large diameter shallow hole that represents the volume of the oil column that theoretically supplies the bottom bearing shell (on a nongrooved lower bearing shell naturally). I'm surprised to see that the rod bearings seem to be unaffected by this since the original intent of cross-drilling was to allow uninterrupted oil flow to them.

So the observation is now, by more engine nerds than just us, that cross-drilling may hurt the main bearings more than it helps the rod bearings. If you are driving over the rods it could be because the mains have already checked out. Maybe the other end of that hole acted more like a scoop which carried the oil away from the bearing and up the hole toward the center. I don't know. As yet I'm not willing to say that any of this is definitely so but there is evidence that says cross-drilling is something we should not be doing to our crankshafts. Katech, for instance, uses a production oiling system on their cranks (built by Sonny Bryant by the way). Strange isn't it, that something like this (non-cross-drilled cranks) which has been counter to the guiding beliefs of high-performance engine builders for many years suddenly becomes accepted procedure. It makes you wonder if race engines would be better off without some other "trick stuff" that we do. Such is the probabilistic nature of engine building.

I don't know who first affirmed the existence of this problem but I'd guess it came from the OE level. Maybe some of this new thinking isn't so new. A 1985 paper by Paul Meernik from the General Motors Research Laboratories characterizes some problems associated with crankshaft oiling. Specifically lubricant flow to connecting-rod bearings through a rotating crankshaft. It shows evidence as to why our EDM'ed holes through the beams of our connecting rods (from the big end to help oil the wrist-pin) probably don't help. It also showed the importance of a lead-in groove on the journal.

So now it's months later and I'm freshening up an engine for a customer (a big-block drag boat) and again I'm having to change the main bearings while the rod bearings are going on their fourth season. I suddenly realize that after every season the main bearings look awful and the rods are perfect. This crank is cross-drilled. I've wondered about this every year and I always changed the clearance one way or another expecting to see better results. This particular big block is used at a higher rpm level (8000 - 9000 rpm) than any of my others (with cross-drilled cranks). This may be evidence that this is only a high rpm problem. A similar observation has been made with the 330 inch Trans-Am motors. I never would have suspected the oiling scheme on my own because through the years I've read and been told (my education) countless times that high rpm engines need cross-drilled main journals.

This problem may not have anything to do with the oil system - maybe we're caught in a PKE surge or a full-flow cross-rip of major proportions (GHOST BUSTERS) and just don't realize it. Maybe the race-gods are just having fun with us again. If nothing else we have **"Laid down a foundation of observation"** (Lederman).

Someone said you can observe a lot just by looking. That didn't help me with this main bearing problem. In Mark Donahue's book THE UNFAIR ADVANTAGE he said if something looks right it usually is right (or something to that affect - I loaned the book and never got it back). In the past however, we have solved several engine problems by observing things that didn't look right.

There are many traps in building and dynoing engines. Traps like allowing your first analysis to be biased by someone else's opinions. Another trap is believing that your data is correct. In testing engines we are victims of several problems. One measurement sometimes undermines the other. In other words the act of measuring influences the results when a transducer of one form or another has to be placed in the system to be monitored. In quantum physics this problem has its own supporting theory called "the uncertainty principle" which says that one can never be exactly sure of both the position and the velocity of a particle; the more accurately one knows the one, the less accurately one can know the other. That might not be a very good analogy but nonetheless we could have this problem when transducers impinge on the fluid to be measured. If the transducer directions and good procedures are followed, these errors are reduced.

The other problem, the one I find the most frustrating, is due to the update time of the data stream when we are doing acceleration tests. The computer does not run fast enough in the Super-flow processor to gather the data fast enough to track an acceleration test. It cannot capture all of this data at exactly (within reason) the same instant. Not only do we get real lags in the fuel, air, oil and coolant flows, we also get data lag. This can cause discrepancies in a particular row of data, depending on the severity of the lag, (this data lag doesn't have much effect on a steady-state test) which further confounds the issue of accurate data interpretation. Lederman said - "**These introduce inevitable distortions introduced by an imperfect apparatus."** I suppose any system will have it's own set of inherent problems. We get bad data, everyone gets bad data, in one form or another, some of the time or all of the time.

How accurate do you need to be? We always want to be as accurate as we can on any measurement despite the accuracy on other measurements. For example we may have .5% accuracy on fuel flow and 10% accuracy on air flow. You cannot trust air/fuel data with that kind of accuracy but since the horsepower is very repeatable we should therefore feel good about the bsfc data.

Everyone has different ideas on what constitutes good data and bad data. Air flow can be measured several different ways of which maybe none are accurate. For example, I've been told Ford has given up on measuring air flow directly and they now calculate it from oxygen in the tail-pipe. **"I mention all these technical details to show you that experimentation is not so easy and that the interpretation of an experiment is a subtle affair"** (Lederman again). Therefore all we can do is present the data within the limits of its trustworthiness. **"It's very rare that we get incisive experimental verification of a theory or idea."** Guess who?

Someone once said to me **"If you torture the data long enough it will give up its secrets."**

We dynoed engines for over ten years with equipment, if compared to what we have now, could be called stone-age stuff. That was before data-acquisition and servo-valves were incorporated into dynos. It was arcane, but we made engines run, made decent power and won races. Our data wasn't very reliable however. We had an ant problem for awhile. Carpenter ants had decided to take up housekeeping in the ceiling above the dyno. You would never see an ant until the engine below them hit about 600 horsepower. At that point ants would rain from the flourescent light fixture above the engine. In those days we didn't have any small blocks making that kind of power so we only saw them when we ran big blocks. The more the power the more the ants. There may have been a hundred or so ants hot-footing it around on the engine after a hard 600 plus HP pull. Whenever an engine would miss at high rpm we could just say it was probably an ant getting sucked in. Anyway we didn't have very good transducers then for gathering data and more often than not we didn't feel very good about the accuracy of our horsepower numbers. Because of our year long observation of the ants we figured if we took the square-root of the room temperature, divided by the ant count on the engine and multiplied that by the scale reading, that we would have a horsepower number as dependable as the equipment would allow.

We've all passed a lot of water since then. We were no less successful then, than now. The amount of data and observations has increased in recent years but I feel just as confused about dynamic engine relationships. My standard of living hasn't gone up - only the standard of HP per cu/in so maybe there has been progress after all. But - **"Is it progress if a cannibal uses a fork?"**

I've really gone off the deep end here, maybe, but I might as well get all this GOD PARTICLE stuff off my chest.

The desire to find truth is a primary motivating factor for physicists. Many physicists believe they are on the verge of finding a complete mathematical description of the universe - a Theory Of Everything. As with any field of endeavor we as engine nerds are also searching for the truth. Our motivating factor is horsepower - which can lead to the three G's - gold, glory and girls. While the Theory Of Everything is a high point of Western culture its IC engine counterpart is the fuel that keeps engine builders, engine related parts manufacturers, parts vendors and magazines in business. Until we have an engine TOE everyone has and is, I suppose, entitled to their own theories or opinions as to the goings on inside this devious device. In fact, these opinions and observations are necessary. **"In any mystery, there are clues - some valid, some false.** Lederman.

It kind of chaps my bottom that they have shows on TV - A&E or the Discovery channel for instance - about science and they never include the IC engine. On one of those channels a while back, for some reason, I was watching a program on archaeology and they made a statement that caused me to run to my computer so I could capture it before it fell out of my little brain. **They said "Archaeology only makes the story plausible, but doesn't prove it happened."** That amazed me. Here is a whole field of science based mostly on theories. They construct a plausible story that fits the observations and - wolla - that's the way it must have been. Who's going to argue with them. But that doesn't mean it's the truth. What's more important, a great sounding theory or the truth? Sounds to me like these are the people who write engine articles for some of the car and boat magazines.

Anybody can form a theory about anything. I've got more theories about women than I do about engines. The dictionary has a lot of definitions of theory. Even after theories are proven to exist, such as the theory of relativity, they still call them theories. Why not the "fact of relativity?" The answer is simple. **There is never irrevocable proof in science.** To paraphrase Winston Churchill again he said **"Success is never final."** And so it is with theories - they are never final. The battlefield of science is littered with the carcasses of great theories, which at one time, were plausible or scientifically acceptable general principles offered to explain various phenomena.

One definition says that a theory is an ideal or hypothetical set of facts. It is only human nature that we want to have a plausible explanation of everything. Sometimes theories are born when observations are made that are so simple and elegant that they just have to be right - but they rarely are. Many theories are formed and the way a lot of magazine articles get published, that is, buy forming a theory around neat, easy to understand, organized and convenient conditions because that is the best sounding or most romantic explanation.

Sometimes equations are formed to support theories and sometimes it has happened the other way around. History has found more than one example where scientists have manipulated their experiments to give results that support their theories. This is ugly science. I have seen evidence of this type of science practiced in dyno rooms for years. **"The test of scientific objectivity is not to let the passion influence the methodology and the self criticism."** Lederman.

Experiment means observing and measuring. It involves the construction of special

conditions under which observations and measurements are most fruitful - Lederman. If we can't repeat someone else's experiment with similar results then it's not a good experiment. Therefore the resulting theory is not a good one. The reason engine experiments rarely produce similar results is because there are two many hidden variables. Just because a particular spacer, manifold or header produces positive results on a 355 inch Chevrolet at SED doesn't mean that the results will be the same when tested on a similar engine at Muppet Labs for example. Because the engines are not similar "enough."

I can't think of one dynamically related engine theory that has really been proven. I'm speaking of the wave and pulse stuff. We know these waves and pulses exist because we can feel them and measure them. But like women, just because we can feel and see them doesn't mean we can understand them. Certainly single cylinder motorcycle engines live and die by these pulses but to get eight of them to cooperate, in an common plenum intake manifold at the same time, according to some theory, is like trying to organize earth worms. Our wave analysis software is fun to play with but it hasn't gotten us much closer.

Thank God that people like Archimedes, Galileo, Newton, Maxwell, Einstein or any of history's other big thinkers had bigger fish to fry than the internal combustion engine or I would probably still be at Tektronix slaving over a hot transistor.

Speaking of Galileo and not believing what you see, Lederman told an interesting little story that points out the problems he had. He didn't get his due respect either.
From The God Particle:
Quarks are even more abstract and difficult to visualize than atoms. No one has ever "seen" one, so how can they exist? Our proof is indirect. Particles collide in an accelerator. Sophisticated electronics receive and process electrical pulses generated by particles in a variety of sensors in the detector. A computer interprets the electronic impulses from the detector, reducing them to a bunch of zeroes and ones. It sends these results to a monitor in our control room. We look at the representation of ones and zeroes and say, "Holy cow, a quark!" It seems so far-fetched to the layman. How can we be so sure? Couldn't the accelerator or the detector or the computer or the wire from the computer to the monitor have "manufactured" the quark? After all, we never see the quark with our own God-given eyes. Oh, for a time when science was simpler! Wouldn't it be great to be back in the sixteenth century? Or would it? Ask Galileo.

Galileo built, according to his records, a huge number of telescopes. He tested his telescope, in his own words, "a hundred thousand times on a hundred thousand stars and other objects." He trusted the thing. Now I have this little mental picture. Here's Galileo with all his graduate students. He's looking out the window with his telescope and describing what he sees, and they're all scribbling it down: "Here's a tree. It's got a branch this way and a leaf that way." After he tells them what he sees through the telescope, they all get on their horses or wagons - maybe a bus - and go across the field to look at the tree close up. They compare it to Galileo's description. That's how you calibrate an instrument. You do that ten thousand times. So a critic of Galileo describes the meticulous nature of the testing and says, "If I follow these experiments on terrestrial objects, the telescope is superb. I trust it, even though it interposes something between the God-given eye and the God-given object. Nevertheless, it does not fool you. On the other hand, if you look up at the sky, there's a star. And if you look through the telescope, there are two stars. It's totally cracked!"

Okay, those weren't his exact words. But one critic did use words to this effect to dispute Galileo's claim that Jupiter has four moons. Since the telescope allowed him to see more than could be seen with the naked eye, it must be lying. A math professor also dismissed Galileo, saying he, too, could find four moons of Jupiter if given enough time "to build them into some glasses."

Anyone who uses an instrument runs into this problem. *Is the instrument "manufacturing" the results? Galileo's critics seem foolish today, but were they off the wall or just scientific conservatives? Some of both, no doubt. In 1600 people believed that the eye had an active role in vision; the eyeball, given to us by God, interpreted the visual world for us. Today we know the eye is no* *more than a lens with a bunch of receptors in it that passes visual information along to our brain's visual cortex, where we actually "see." The eye is in fact a mediator between the object and the brain, just as the telescope is. Do you wear eyeglasses? You're already modifying. In fact, among devout Christians and philosophers in sixteenth-century Europe, wearing spectacles was considered almost sacrilegious, even though they had been around for three hundred years. One notable exception was Johannes Kepler, who was very religious but who nonetheless wore specs because they helped him see; this was fortunate, given that he became the greatest astronomer of his time.*

Let's accept that a well-calibrated instrument can provide a good approximation of reality. As good perhaps as ***the ultimate instrument, our brain.*** *Even the brain must be calibrated at times, and safeguards and fudge factors applied to compensate for distortion. For example, even if you have 20/20 vision, a few glasses of wine can double the number of friends around you.*

I provided the bolding because I thought these statements warranted it.

I interpret this to mean that, based on common sense and what we observe, we must recalibrate our brain by inserting safeguards and fudge factors to override what we have been formally taught. Maybe that is what someone meant when they said **"What you see depends mainly on what you look for."** As he said in the first sentence, we also base some of our opinions about how engines work on indirect evidence. That is how it's going to have to be until someone finds a little guy who can go in there while the engine is running and give us a report on what he saw. He's going to have to be able to withstand much heat and pressure and wear earplugs because it's probably going to be real noisy in there. The trouble is if he's not technically oriented, that is, not an engineer or an engine nerd, how can we believe what he tells us because we will still have to interpret his data and compare it against our own.

"Observation more than books, experience rather than persons, are the prime educators." - Amos Bronson Alcott.

If you believe a task or goal to be impossible you will never achieve it. However if no one has taught us that something can't be done it's likely we will achieve much more.

I like hearing others peoples engine theories. Especially if they operate dynamometers. Even though I don't always agree with them it's possible to gain insight to a problem by hearing someone else's interpretation of it. It's common for different people to draw different conclusions from the same data or observations. Sometimes it is easy to miss what your data is screaming at you. Which brings to mind a little parable.

> A budding research scientist in junior high school, was conducting an experiment on a grasshopper on a table, leaned down until his face was inches away from the insect, and screamed, "JUMP!" The grasshopper leapt into the air.
>
> He carefully removed one of the insect's legs. Then he leaned down and once again screamed "JUMP!" The grasshopper responded as before.
>
> He repeated this process four more times, each time removing one of the grasshopper's legs. Each time, the grasshopper leapt into the air, though each leap was less impressive than the one before.
>
> Finally, he removed the last leg. Then he leaned down and screamed one more time. The grasshopper didn't move. Satisfied, he opened his journal and entered the results of his experiment. As a conclusion, he wrote, "When all six legs have been removed, the grasshopper becomes deaf."

A joke? Maybe - but a scenario repeated all too often. We have made equally inept observations and not realized it until another observation or a piece of insight from someone else caused the light to come on.

Thank God engines are not as easy to understand as they appear. I find it especially refreshing to hear someone in this industry, especially someone who has earned respect, admit that they do not know as much about the IC engine as they would like. The man, who in my opinion, has pioneered this unique concept is Jere Stahl. I see him as what Lederman describes as the "intellectual iconoclast" in our discipline. I was lucky enough to get one of his newsletters a few years back, in which he talked about the humbling experience of dynoing and some of the problems of interpreting data. I was impressed with what he said about engine testing and I could see where we had much to gain by changing our cell and testing procedures. And we did. Many of the things he talked about we had already learned on our own, the hard way (like alcohol explosions in the tailpipes). I appreciated the open candidness with which he wrote. Because of his willingness to share his experience with others he has helped us to make our data more repeatable and more accurate. Perhaps not as accurate as he would like it or as accurate as we would like it, but for now until time and money permit, we will continue with what we have. I would really like to buy his new dyno software.

I was most impressed however, when I called him to order a camshaft. In the ensuing conversation he was eager to admit that he didn't know how headers worked. So here's the guy who has probably built and tested more exhaust systems than anyone, saying he doesn't know how they work. That blew me away, but more than that it impressed upon me that it may be OK to publicly admit that you don't know as much as some other people have claimed they know. Certainly some of his competitors claim that they know how headers work. They have low entropy and Jere is a high entropy guy. It impressed me even more when he wouldn't sell me a cam. I've become an adherent of Jere's.

I think I'm beginning to understand why Jere, ourselves and probably most other testers of race engines, don't understand how headers or many other pieces of the engine work is because of "*Verwandlungsinhalt*."

This brings me to the other book I recently read. It's *THE RECURSIVE UNIVERSE* by William Poundstone. He describes the discoveries of modern physics and demonstrates how complexity may originate from simple rules. One of the main things he talked about throughout this book was the similarity between thermodynamics and "information theory." Early in the book he describes the origins of thermodynamics and explains entropy. Once again however, I have to relate what seems to me to be great analogies between, life, physics, cosmology and dynamometery.

German physicist Rudolf Clausius, around 1850, invented a new mathematical quantity. He first called the quantity *Verwandlungsinhalt*, meaning "transformation content." Later he settled on the shorter name *entropy,* Greek for "turning into."

So what is "entropy." I first ran across this technical term years ago in the book *THE DESIGN AND TUNING OF COMPETITION ENGINES (my electronics education did not include thermodynamics)*. The book was vague about it and since I thought I might need to explain it to my engine class, (1974 and my first class) I decided to look it up in the dictionary. Webster has three definitions for entropy - here they are - pay attention.

> **en-tro-py 1 a:** a measure of the unavailable energy in a closed thermodynamic system so related to the state of the system that a change in the measure varies with change in the ratio of the increment of heat taken in to the absolute temperature at which it is absorbed **b:** a measure of the disorder of a closed thermodynamic system in terms of a constant multiple of the natural logarithm of the probability of the occurrence of a particular molecular

arrangement of the system that by suitable choice of a constant reduces to the measure of unavailable energy **2:** a measure of the amount of information in a message that is based on the logarithm of the number of possible equivalent messages **3:** the degradation of the matter and energy in the universe to an ultimate state of inert uniformity

Based on these definitions I decided it would be better if I didn't bother my engine class with entropy. Poundstone, however, has broadened my understanding of entropy.

It is Webster's second definition that relates to information theory and describes our problems. I don't pretend for a moment to understand information theory but this book showed that it is a real entity in the discipline of thermodynamics. He talked about entropy and how it relates to information theory throughout the book.

Poundstone had some interesting things to say, as did Lederman, about observation. A large portion of this book is about observation. To quote Poundstone; "**Science is empirical. It is based solely on observations. But observations is a two-edged sword. Information theory claims that every observation obscures at least as much information as it reveals. No observation makes an information profit. Therefore, no amount of observation will ever reveal everything - or even take us any closer to knowing everything."** He talked of physicist Leo Szilard discoveries on the limitations of empirical knowledge: **"An experimenter's information about a system is a vital part of the system, Szilard found. "There is no such thing as an omniscient, aloof observer." "The act of making an observation changes the system observed."** Szilard and those who continued his work exposed the folly of aspiring to total knowledge of anything. Observation of a system drives up the entropy cost of more precise observation. There comes a point at which any observation is choked off - it ceases to yield enough information to pay for itself.

Entropy is a measure of the disorder of a system. In most experiments (especially dynamometery), the information gained is usually outweighed by new questions that the information generated. Therefore there is a increase in entropy. As experiments create more questions (confusion) and therefore more disorder we are increasing our entropy. Poundstone pointed out; **"Disorder is a difficult concept to pin down, and many obvious means of definition fail. It is reasonable to wonder whether disorder can be objectified at all. Disorder seems subjective - in the eye and expectations of the beholder."**

The book speaks of entropy and these other terms at the molecular level. The author uses everyday situations to make analogies which show the how information theory can be applied to virtually anything.

Take his example of Claude Shannon: **"Shannon noticed the similarity between thermodynamics and information. He came to formulate information in terms of the freedom of choice involved. A message specifies on possibility out of a "menu." The more items on the menu, the more information embodied in the choice. Shannon's definition purposely avoids all meaning or aesthetics that might enter into a message. He realized that these were culture-bound issues for more complex than his study could encompass.**
He goes on: **Information and entropy fit together hand-in-glove. Von Neumann is said to have advised Shannon to adopt the term Entropy in information theory: "No one knows what entropy is, so in a debate you will always have the advantage. Mathematically,**

Shannon's information and Boltzmann's entropy both take the form of the logarithm of a number of possibilities. Think of it this way: The greater the number of items on a restaurant menu, the greater your uncertainty about what the diners behind you are eating. This uncertainty is entropy. The bigger the menu, the more you must say to the waiter to make you choice clear. What you need to specify to eliminate all uncertainty is information.

So it is with engines. How often have we changed an engine component, or re-tuned it in some way, expecting a particular change but got something unexpected. The only dyno operator who never encounters these joys is probably God's personal engine tuner. Nowhere must acquired knowledge be more subjective than when it is applied to the dynamic functioning of the internal (or infernal) combustion engine.

So I go along happily for years because I *know* how the bottom end and oiling system of the engine works. Then I make an observation and, POW! My confidence is shattered. Many new questions arise. Is cross-drilling really the problem or is it clearance - maybe oil viscosity - maybe the maincaps are moving - and maybe - and maybe? Disorder is higher and I have therefore increased my entropy. "**The older I grow, the more I distrust the familiar doctrine that age brings wisdom" -** H. L. Mencken. Since I am not young enough to know everything, (entropy's too high) the more I'm around low entropy people, the lower my tolerance for "engine experts." **"He who devotes sixteen hours a day to hard study may become as wise at sixty as he thought himself at twenty."**

Einstein first postulated "hidden variables." and he spent his middle and later years in a fruitless search for a "unified field theory." There are far too many variables in the internal combustion engine for anyone to ever completely "figure them out." As I have said before every component in the dynamic flow path can have an influence on any or every other part. It would take a googol of parts combinations to arrive at the perfect engine combination and state of tune that would allow it to produce its maximum potential horsepower for a given set of atmospheric conditions. Perhaps the biggest variable of them all is the combustion process itself.

In the book there was an analogy made involving dominoes and the GUT (Grand Unified Theory). That caused me to think about combustion and what must be a googol of variables that influence it. The combustion process is the only part of engine dynamics that really happens at the molecular level and, is therefore, subject to quantum uncertainty.

Think of the cylinder being charged with millions of tiny dominoes. Visualize every combustible molecule of fuel/oxygen as a domino standing on end. Dominoes laying down represent fuel, oxygen, nitrogen or some other molecule that resists burning or won't burn at all. From the time the intake valve closes to ignition these dominoes are changing chaotically from instant to instant and point to point.

At the time of ignition - Physicist call this Planck time (after German physicist Max Planck - this is time up to 10^{-43} seconds before the big bang) and engine nerds call it reaction time, some of the dominoes will be left standing and some will not. The dominoes standing nearest the spark will start falling in familiar chain reactions. These chain reactions go off in many different directions. A given chain reaction propagates until they encounter a space where there is no standing domino and their propagation dies while other reactions are continuing. Quite likely as heat builds up some of the upright dominoes on the "other side" of a empty space or place where dominoes were lying, are set into motion and another chain reaction is started. There are many conditions that can cause these strings to be started and ended.

The speed and direction of these chain reactions is governed by many variables. The more obvious variables sound familiar; the point by point temperatures of the surrounding walls, the eddies, shock waves, and other turbulent phenomena of fluids. Even in a very uniform gas, there will be density fluctuations. Parts of the gas will have a slightly greater density or ratio of fuel and other assorted molecules. A greater density means not only a greater kinetic energy as it enters the chamber but a different thermodynamic characteristic as well. These will cause speed variances within the individual chain reactions. Because of quantum uncertainty the odds of two of these combustion processes occurring with exactly the same characteristics are zero.

This thermodynamic inconsistency is, in part, responsible for the low thermal efficiency of the IC engine.

"The surprising conclusion of information theory is that experiments done within a system can never increase total knowledge of that system at the most fundamental level. All knowledge is counterfeit. Acquisition of knowledge about one part of the world requires an equal sacrifice of knowledge about other parts. Ignorance can at most be shifted around." That was the heart of Szilard's thesis. Any increase in knowledge about one part of an entity is compensated by increased ignorance about the rest of the thing.

How many times have we set out to test headers, manifolds, carburetors or camshafts only to have our results obscured by observing changes in the fuel curves. Usually the change of one component changes the requirements or calibration of another component. That is why it is so hard to learn or develop "general" theories of how engines work. It's more feasible to just say that a particular combination of parts produces these results and compare them to another combination of parts.

Perhaps, as engine builders and small-time experimenters, we should not be in a quest for a complete knowledge of the engine. Rather perhaps, it should be a process whereby certain dynamic engine theories are selected as being more relevant to a particular application. After all, like Einstein, we don't want to spend the rest of our lives in a futile search for something that more than likely doesn't exist.

In the real world the entropy of the universe must increase irreversibly every second. Our information entropy can never decrease in our discipline any more than it can in thermodynamics. Entropy, in turn, is ignorance - typically applied at the molecular level but in our case it's with a simple engine. Not, however, as simple as many make it out to be. Sure, there are probably a few simple rules that govern it but as Poundstone said: **"Simple rules can have complex consequences. *This* simple rule has such a wealth of implications that it is worth examining in detail."**

This is Lederman quoting Feynman:
In the essay "What Is Science?" by the late Richard Feynman he admonished the student: **"Learn from science that you must doubt the experts. . . . Science is the belief in the ignorance of experts."** And later: **"Each generation that discovers something from its experience must**

pass that on, but it must pass that on with a delicate balance of respect and disrespect, so that the race . . . does not inflict its errors too rigidly on its youth, but it does pass on the accumulated wisdom plus the wisdom that it may not be wisdom."

This eloquent passage expresses the deep training in all of us who have labored in the vineyard of science. Of course, not all scientists can summon the critical juices, the mixture of passion and perception that Feynman could bring to an issue. That's what differentiates scientists, and it is also true that many great scientists take themselves too seriously. They are then handicapped in applying their critical powers to their own work or, worse still, to the work of the kids who are challenging them. No discipline is perfect. But what is rarely understood by the lay public is how ready, how eager, how desperately the collective science community in a given discipline welcomes the intellectual iconoclast - if he or she has the goods.

Common sense is in spite of, not the result of, education. We are victims of our education. Sometimes we overlook simple answers to problems because we try to make them more complicated than they really are. Maybe the better we are educated in a science the harder it is to break away from theories built on shaky foundations but are nonetheless firmly ensconced in the community mainly because no one has bothered proving otherwise. There is no profession immune from this problem. Hubert Humphrey put education into perspective when he said; **"I learned more about economics from one South Dakota dust storm than I did in all my years in college."** And Mark Twain; **"I've never let my schooling interfere with my education."**

It's all too easy to make quick evaluations based on something you once read in a nonscientific magazine or were told by someone who has a knack for making conjecture sound like fact. There are two kinds of proof, proving something to ourselves and proving something that changes the mind-set of an industry. The latter rarely happens to anyone but the former happens quite often when you dyno engines. We realize that a particular theory *du' jour*. might not hold up in a court of physics but until we can figure out what is really happening it doesn't matter - it's our theory and we either reap rewards from it or choke on it. You can't take back an observation. Sometime in the future a set of conditions may occur that causes us to modify this theory or throw it out entirely. If someone comes up with an opposing viewpoint we win two ways. If we can see where our observation could have been clouded by too many hidden variables that's good because it gets us back on track. If we determine our data is more reliable - that is, we can't find any flaws in our procedures - then it only makes us feel better about our theory. Lederman said, **"All we can ask of a theory is to predict the results of events that can be measured."**

These books put many things into perspective for me. For instance, things that are problems for us are the same problems encountered in all of science, in all types of laboratories no matter the smart-a-tude of the people involved or the cost of their equipment. Lederman said something that and is, I guess, the message I have tried to put behind this paper - **"Learn from science that you must doubt the experts. . . Science is the belief in the ignorance of experts."**

Pat Usher