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Fuel-Air Factors

An engine produces maximum power only when the fuel-air mixture is exactly right – a change in either direction, increasing or decreasing the amount of fuel in relation to the amount of air, will always DECREASE power.

For most practical purposes, your body is an engine – and many of the same basic principles can be applied with equal validity to an engine or to a human muscle and its supporting organs.

In 1955, I bought a new car – and I maintained an exact record of its performance during the time that I owned it, for 68,000 miles; during the entire period of ownership it averaged 15.8 miles to the gallon, overall –highway driving, city driving, and some outright competitive racing. When driven at a reasonable speed, a true 60 miles an hour – which, on that car, when the tires were new, was 64 miles per hour on the speedometer – it gave an average of well over 20 miles to the gallon, and sometimes as much as 22 miles to the gallon.

Ten years later, in 1965, I bought another new car of the same make – and by that point my driving habits were much improved; which should have resulted in even better gas mileage – but, in fact, I was lucky to get as much as 12 miles to the gallon even on the highway, and the average mileage was about 10 miles to the gallon.

The two cars weighed about the same, had basically the same "extras", and should have performed in a very similar fashion – but in fact, the 1955 car was faster, had much better acceleration, and used a lot less fuel.

At first I didn't understand why – but now I do; the later model car was designed to use an "over-rich" fuel-air mixture for cooling purposes – the engine was literally being cooled by the use of excess fuel.

During that period of ten years, the size of the engine had been increased, the compression ration had been increased, the "advertised" horsepower had been increased, fuel consumption had gone up enormously – and the car weighed about the same and performed a lot worse; because the engine had become so big it couldn't be cooled adequately in the normal way – it was creating more heat than the cooling system could handle.

So how did they solve the problem? In a logical way, by reducing the size of the engine to a point where the cooling system could cope with the situation? Of course not – because then they couldn't advertise the huge size of the engine; size they couldn't use in a logical manner – a lot of which size, and potential power, they couldn't use at all.

In an airplane engine, where you do have adequate cooling (at least in the air), the maximum power setting of a fuel-air mixture will also be the fuel-air mixture that produces the most heat – and the same thing is true of any engine; during takeoff, when the engine is actually operating above safe limits – producing more power than it is really safe to use – you must use an over-rich fuel-air mixture, which will obviously reduce the power production somewhat, but which is compensated for by using more revolutions per minute and higher manifold pressure.

But when cruising power settings are being used, the situation is somewhat different – then you are interested in getting as much power as you can out of each gallon of fuel; and when the fuel-air mixture is regulated to give maximum power, you will also be creating maximum heat.

In practice, most airplanes aren't cruised at such fuel-air settings, because it is more economical to use a mixture that actually gives a bit less power; an airplane is designed to cruise within a certain speed range, and any speed outside that range is highly inefficient – flying slower, or flying faster, in either case the fuel consumption will be increased. Secondly, a slight increase in speed requires a disproportionate increase in power – to increase the speed by 10 per cent you might have to increase the power by 100 per cent, so it isn't justified.

So in practice, you try to use the fuel-air mixture that will give you the most miles per gallon – even though that mixture won't give you quite as much power, or, at least, that's the way you should do it, the intelligent pilots do it – which means, of course, that it is NOT the way most pilots do it. Instead, most pilots actually reduce the power, and the speed, while INCREASING the fuel consumption.

If you are cruising at an indicated speed of 200 miles per hour, and if your engines are turning at the correct number of revolutions per minute, and if your manifold pressure are proper for the circumstances – then your engines will also be producing maximum heat, and you may be burning a total of 400 gallons of fuel per hour (100 in each of four engines); which means that you are burning two gallons of fuel for each mile of indicated speed.

But you are aware that a rather large scale reduction of power (and thus a large reduction in fuel consumption) will not produce a proportionate reduction in speed – so it is only common sense to use a more economical combination of power and speed factors; so you reduce the power by moving the mixture-control levers in the direction of a "lean" setting, you reduce the amount of fuel being fed to the engines but leave the air input just as it was – and both the power and the heat start to drop off.

And the speed drops as well – but not in proportion to the reduction in fuel consumption; with a proper mixture setting, you may be burning only 300 gallons per hour – but you are still getting 190 miles per hour speed, so you are then getting far better fuel consumption; in effect, by reducing your speed only 5 per cent you reduced your fuel consumption by 25 per cent, an obvious improvement.

But that is the PROPER way to do it – and how do most pilots do it? By moving the mixture levers in the opposite direction, by giving the engines MORE gas instead of less gas – which will have exactly the same effect as far as power and heat are concerned, both of which will be reduced. And as the power drops off, the speed will also drop off. But what about the fuel consumption? Well, instead of dropping off from 400 gallons per hour to only 300 gallons per hour, it will increase from 400 gallons per hour to possibly 500 gallons per hour – instead of getting better, the situation gets worse.

If you ask a pilot that does this "why he does it", you may get almost anything for an answer – anything but a rational answer, that is; but usually they will mumble something about "playing it safe." Whatever that means.

And if, by this point, you are wondering just what all of this has to do with physical training – then wait a bit, it will all come clear in a moment.

As I mentioned a page or so back, your body has much in common with an engine – your body also requires a proper fuel-air mixture, and like an engine it likewise requires a proper chemical mixture in the fuel itself; if the mixture is changed – in either direction – then the result will be a reduction in power, NEVER an increase, ALWAYS a reduction.

Yet, much like pilots that really don't understand the involved factors, most bodybuilders constantly think they are "playing it safe." By giving their body an amount of one element of fuel that is out of proportion to the other required elements. And all they are actually doing, of course, is overloading their systems – providing a mixture that cannot be used properly; wasting fuel and reducing power at the same time – and throwing at least some strain on their organs for no good reason.

An airplane engine cannot convert fuel to air, and if you give it too much fuel in proportion to the amount of air it is getting then it will simply quit running entirely; but the human body can convert certain food elements into other elements if it is required to do so – and it will do so, up to a reasonable point. But there are limits – and if pushed too far, the body may not stop running entirely but will certainly start operating at greatly reduced efficiency.

While it may or may not be true, as many self-appointed "nutritional experts" maintain, that Americans are the WORST FED people on earth – if so, then bodybuilders are the worst of the lot.

Unfortunately, the human body doesn't come equipped with instruments to tell us just what is happening at the moment – not on a dial, at least; but the body will tell you quite a bit about what is happening if you know how to read the signs – and if you can't, but if you can at least read English, then you can learn what to do from somebody who can read the signs.

Twenty years ago, most bodybuilders had probably never heard of protein –today, most of them try to restrict their diets to almost pure protein; and when that doesn't give them instant results, then they try to force their system to use more of the protein by taking drugs – and most of them end up fat as a pig, wondering what happened. What happened, of course, was that the body did the only thing it could do under the circumstances – not being able to use the protein in the amount supplied, it converted it to fat.

And quite a few of them, as a result of the drugs, end up with greatly-reduced interest in girls, or, even if they maintain their interest, they can't do much about it.

In an airplane, in certain situations where operation is NOT NORMAL, it is permissible – even recommended practice – to vary the fuel-air mixture for reasons other than the one outlined earlier; but in all such situations the efficiency will be reduced, and it should also be noted that all such variations will reduce the power output to a point well below that which might me indicated by fuel consumption, by revolutions per minute, by manifold pressure, or by any other means of calculation.

And the human body is subject to very similar physical laws – and if all of the involved factors and their interrelationships were clearly and exactly understood, then it is at least probable that the physical laws would be found to be identical; and to the degree that they are known, they are identical – with no SINGLE EXCEPTION that can be supported on any basis except outright myth.

All of which is so simple, so basic, so obvious, so undeniably true that I am almost embarrassed to write it – but most of which will sound like outright heresy to many bodybuilders, perhaps to most bodybuilders.

You might also take note of the fact that varying the fuel-air mixture from "lean" to "rich" also changes the octane rating of the fuel – literally reduces the power of the fuel; kindly note, LOW OCTANE fuel is MORE POWERFUL than high octane fuel.

You cannot safely use low-octane fuel in a high-compression engine – but not because it isn't powerful enough; on the contrary, it isn't safe because it is TOO POWERFUL. And high-octane fuel, of course, can be safely used in ANY engine – because it isn't powerful enough to be dangerous; and if you raise the octane rating high enough, then the fuel won't even burn.

All of which, of course, is exactly the opposite of what most people believe.

And while I am certainly not suggesting a low-protein diet, and while a diet that is slightly rich in protein may be an advantage during periods of rapid growth – there is a very definite limit to the amount of protein that can be used by the body under any circumstances; and if you exceed that limit, the results will be WORSE rather than better.

In many cases, the diets of bodybuilders are merely foolish – but in no small number of cases, they are actually dangerous.

And now we come to the real point of this chapter – which might not have been clear without the preceding examples; the human muscular system also depends upon a very definite fuel-air mixture for proper performance – or even for life itself.

Without becoming bogged down in lengthy descriptions of all of the factors involved, things like "steady state" function and "oxygen debt" limitations, I will attempt to make the reader aware of the implications of all of the related cause-effect relationships; again it isn't necessary to understand just "why" such situations exist, if we are at least aware of the practical considerations.

To function, muscles require oxygen – in proper ratio to the available fuel; to that degree, muscles and engines are exactly alike – but muscles, unlike an engine, can store oxygen, and can borrow oxygen. In effect, a muscle can and will use oxygen from sources that are not normally called upon; and thus it is able to function longer than might be expected – but there are limits to this ability as well.

For proper results from exercise, these limits must be understood and allowed for; if not, then the usual result is that a point of failure is reached because the muscles simply run out of available oxygen – they will quit functioning, they MUST QUIT functioning, because the fuel-air mixture becomes unbalanced to the point that the still available fuel cannot be used. And if this is allowed to happen, then you can repeatedly work to a point of actual failure without doing much in the way of stimulating growth; because, if failure results from a simple lack of oxygen rather than from true exhaustion of the reserve ability of the muscles, then you obviously are not working within the momentarily-existing levels of reserve ability.

In very simple terms, this means that you must work fast – and that the amount of work must be limited to a certain maximum number of repetitions; in following chapters I will list several suggested training routines – which are not based upon guesswork, and which must be performed exactly as outlined if the results that they are capable of producing are to be realized in fact.

"Yes, but different people react differently" (or words to that effect), is a statement I have heard from hundreds of bodybuilders; and the idea expressed is certainly true – up to a point. But it is equally true – and of far more importance – that the basic laws of physics are the same for EVERYBODY.

In practice, we found that the number of repetitions should remain within certain fairly rigid limits – and we understand why these limits are imposed; in previous chapters, I have detailed points that should make the lower limiting factors clear to anybody, so I will add very little in that regard here – and the above should help to explain at least some of the upper limiting factors.

All that remains, then, is to state those limits in simple terms; in general, the number of repetitions should be not less than six nor more than twenty – and in many exercises, limits of 8 to 12 repetitions should be observed.

If you practice less than six repetitions, it is unlikely that you will actually work far inside the momentarily-existing level of reserve ability – and if you exceed twenty repetitions, you will probably fail from a lack of oxygen, rather than from having reached a point of actual muscular failure, and again you would not be working inside the levels of reserve ability.

We do, on an occasional basis, perform sets of as few as four repetitions – but in general, sets of such a limited number of repetitions are not advisable; they are dangerous if performed in a proper style, and will accomplish little or nothing if not performed properly.

It should also be obvious by this point that doing "more" exercise is NEVER the proper solution, and that no amount of extra exercise can compensate for exercises performed improperly; the style of performance of any exercise is perhaps the most important point of all – and this is far from being a simple matter, involving, as it does, such factors as proper resistance selection, speed-of-movement, calculated variation of power production from repetition to repetition, and other factors of equal importance.

"And," you may be asking at this point, "what does the difference between the performance of the 1955 car and the performance of the 1965 car have to do with the matter?"

Quite a lot; that was merely an example of the fact that the ratio of efficiency of the cooling system has a great deal to do with the ability to make practical utilization of potential power – in a car, or in a man. This one factor is responsible for a lot of the obvious differential in the performances of light-weight lifters and heavy-weight lifters; and it is also a factor to be reckoned with in training.

In an earlier chapter, I mentioned that an increase in mass will always be out of proportion to the simultaneously occurring increase in surface area – and that heat is produced in proportion to mass, and cooling is provided in proportion to the surface area; which simply means that an increase in size will always result in a decrease in cooling efficiency – as you get larger, you get warmer.

And it should also be remembered that maximum-possible power production simultaneously and unavoidably produces a maximum-possible heat rise; which simply means that actually hard work must raise the temperature of the body. And since the body's efficient operating range is extremely narrow insofar as internal temperature is concerned, this means that a large man will not be able to sustain actually hard work as long as a smaller man can –everything else being equal; and this, I think, is another reason why most advanced bodybuilders fall into a habit of working at a lower intensity of effort and at a slower pace, with more frequent and longer rest periods between sets – which, in turn, reduces their production of results.

So again it should be obvious that you simply cannot escape the basic laws of physics – and that these effects must be understood and allowed for; if not understood by the trainee – and they seldom will be – they must, at least, be understood by the coach, or by the person outlining a program of training. And for the production of an actually worthwhile rate of progress from physical training, a program that is designed with these limiting factors clearly in mind must be followed exactly as it is outlined.

Remember – you can have an elephant's body, an elephant's head, four elephant's feet, and all of the other required parts, but you still won't have an elephant if all of the required parts are not fitted together properly.

Yet, in practice, I find that most bodybuilders start "changing things" almost immediately after they have been given a training program; and then wonder why they don't get the results they expected.

"Well", you may be thinking now, "this still doesn't justify a detailed description of the best fuel-air mixture settings for an airplane."

But perhaps it does; and in any case, that example was carefully chosen for a particular reason – or, actually, for several reasons, since there are several parallels with situations commonly encountered in weight-training. Some of which parallels have already been mentioned – the fact that maximum power production unavoidably involves maximum heat production, the fact that an over-rich mixture actually reduces power production, and the fact that many bodybuilders (like most pilots) mistakenly feel that they are "playing it safe" by operating with an over-rich mixture – and some other parallels that might not be clear at this point.

While cruising, the pilot of an airplane should be primarily concerned with operating his engines for maximum economy – in order to extend the range and in order to avoid undue stress on the engines; and many bodybuilders train as if they were trying to do exactly the same things – apparently for much the same reasons. While, of course, they should be trying to produce the results that the pilot is trying to avoid; they should be trying to impose "stress," and "extending the range" of their workouts is certainly not desirable.

A pilot should understand that increasing his cruising speed by as little as 5 per cent may require increasing his power output (and thus his fuel consumption) by as much as 100 per cent – and that doing so will obviously reduce his range; and a weight-trainee is faced with much the same situation, but with a difference – inducing growth-stimulation requires maximum-possible power production, which will unavoidably "reduce the range", make long workouts literally impossible.

And again, confusing the "amount of exercise" with "intensity of effort", most bodybuilders soon fall into a pattern of training more, but never actually training very hard.

If you train properly, you don't need an actually large "amount" of exercise; more than that, if you train properly, you can't STAND much exercise.

A distance runner is interested in one thing, a sprinter is interested in something else; the distance runner literally must operate under "steady state" conditions that will permit long range operation – the sprinter must use all available power for one quick burst of speed. The distance runner certainly works more – and the sprinter just as certainly works harder; distance runners seldom have much in the way of muscular mass or strength – while good sprinters frequently do have impressive muscular mass in their legs, and are actually quite strong.

For the purpose of building muscular size-strength, it is important to perform "as much work as possible" within a "strictly limited time period", the period required to reach a point of actual muscular failure, and a period of time that is below the limit imposed by fuel-air factors.

Which adds the following to the list of basic points . . .

43. Exercises involving maximum power production must be performed at a fast pace, with little or no pause between repetitions.

44. The number of repetitions should be at least 6 and not more than 20 in all sets – and at least 8 and not more than 12 in some exercises.

45. Increasing the "intensity of effort" requires a disproportionate reduction in the "amount" of exercise.

46. A point of failure must be reached as a result of muscular failure.