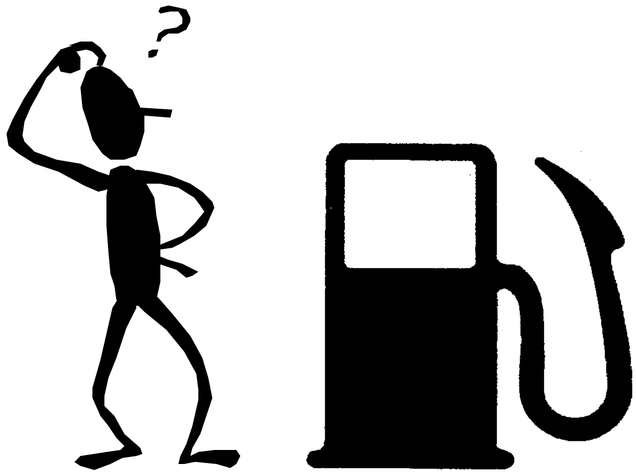


Fuel Octane Rating for Recreational Engines

How important is it to pick the right one?

When you drive into your local petrol station, something most of us do on about a weekly basis, you have a choice of 2, 3 or even 4 different grades of petrol (gasoline) to choose from. But it's rarely a difficult choice.

When it comes to road vehicles, most of us are driving a locally made vehicle, or an imported vehicle made specifically for Australian and New Zealand conditions. Therefore the owner's manual, and labels on the vehicle, will be written so the specifications match local terminology. Fuel requirements will be something like "use ULP or unleaded petrol". Here's an example, (Holden Commodore VX series) -

FUEL	Supercharged engines	Premium (95 octane) UNLEADED petrol
	Non-Supercharged engines	Regular UNLEADED Petrol of 91 octane or higher.

Petrol station fuel pumps are marked with similar words, that's why it's not such a difficult choice, but what if you are using imported equipment that may not match the local terms? Can you easily get into trouble by picking the wrong fuel? Unfortunately, the answer is yes.

You'll notice the word Octane is used a lot when describing fuels. Of course, that refers to a rating given the fuel for its resistance to detonation. Higher octane ratings mean greater resistance, which is what higher output, more highly stressed engines usually need. The name comes from one of the laboratory fuels used when measuring octane ratings, iso-octane (see attached story on octane rating history).

Ever since the octane ratings were first established back in the 1930's, that word has been used around the world, but (and here's where we can get into trouble) there is more than one type of octane rating method and not all countries advertise the same one. There are two basic octane measuring methods, the Research and Motor methods, plus some derived versions like AKI (Anti Knock Index) or Pump Posted octane numbers (see attached story on where these names came from).

The Motor rating came first, is a more severe test and represents engines under high load, full throttle conditions. It's usually abbreviated to MON (Motor Octane Number).   The Research method was developed to represent engines under lighter load, part throttle conditions more like those commonly found in road vehicles. It's abbreviated to RON (Research Octane Number) and is usually a higher number than the Motor rating. The AKI or Pump Posted numbers are derived by averaging the MON and RON ratings for a given fuel.

Here's how the currently available Australian automotive fuels rate in the various systems –

Fuel Type	MON Minimum (1)	MON Typical (2)	RON Minimum (1)	RON Typical (2)	AKI or PP (3)
Unleaded (ULP)	82.0	82.5	91.0	91.5	87
Premium Unleaded (PULP)	82.0	85.5	95.0	96.3	91
Lead Replacement Petrol (LRP) or Super	--	85.5	96.0	96.3	91
High Octane, (BP Ultimate, Shell Optimax, etc.)	--	87.0	--	98.5	93

Notes (1) - Minimum specified in Australian Standard, where applicable.
(2) - Typical average at Australian refineries.
(3) - Anti-Knock Index or Pump Posted octane, as used in USA based on Typical octane numbers and rounded up to whole number.

You will see that the MON, RON and AKI numbers for each type fuel are quite different and this is where the potential problems arise. You need to know exactly which octane rating you are looking for when the vehicle's specifications says something like "use 91 octane".

Australia and New Zealand oil companies generally show the RON number when advertising local fuel octane numbers. This is partly because the RON method is intended for light load applications like road vehicles and partly because (from an old fashioned marketing viewpoint) the larger numbers look better in print. However, other countries are different. Various government legislation around the world requires other ratings to be advertised and of course, some petrol powered equipment is used in high load, high rpm conditions where the RON rating is not the most appropriate.

The recreational petrol powered equipment market is not as big as it is for road vehicles, so often just one or two varieties of a vehicle are used all over the world. Same with the Owners Manuals or Operators Guides, one version for several countries. That means the English language version we see will most probably be written for the largest English speaking region, North America.

Here's a couple of examples for high performance recreational vehicles –

Personal Water Craft made in USA –

Fuel	Type	Super Unleaded Gas
	Minimum Octane number	91

Here you can see there is no specification for which type of octane number is called up, but knowing it was made in the USA primarily for that market, it will AKI as that is required on petrol pumps by law there.

Off-road All Terrain Vehicle, made in Asia –

Fuel	Type	Super Unleaded Gas
	Octane	91 (R + M)/2 or higher

Here more info is provided about which octane is required. "(R + M)/2" means Research plus Motor, divided by two, which is exactly the way that AKI is calculated. However, the term AKI is only commonly used in the USA, so the method of calculating is often listed for more international models.

Light Aircraft engine, made in Europe –

Fuel	Type	Leaded or unleaded, or Avgas 100LL
	Octane	Minimum RON 95, 91 AKI

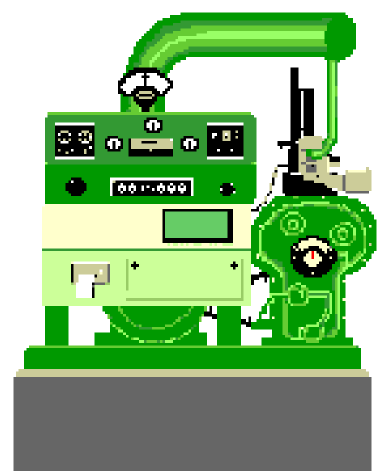
Here's a different way of saying basically the same thing. Most gasolines that meet 91 AKI will also be 95, or more, RON. Both are listed here so that different markets will be able to recognise the correct local grade. The low lead version of Avgas (100LL) is also listed because where this engine is used it's likely to be available and meets the requirements.

In Australia or New Zealand all three of the above engines would need to use PULP or a higher octane fuel, to meet the minimum requirements. That's because when you look behind the numbers and determine the spec's are written primarily for the North American market, then its clear that we need 91 AKI or 95 RON. However if you just noticed the "91" and thought to yourself "That's the RON number for ULP, so ordinary unleaded is OK", then you could very soon be in expensive engine trouble.

How can you tell? It's not easy because recreational vehicle fuel requirements are written for the most likely country of destination. In the English language that's usually North America, but not always. If you can't tell just where the vehicle's fuel requirements are intended for, then it usually safe to assume it's North America and consider the octane number to be AKI. That way you might end up spending a little more on fuel, but it's much better than the severe engine damage from detonation that might result when you use a low octane fuel in a high performance engine.

Fuel Octane – A Little History

Detonation is the name given to the very rapid and uncontrolled combustion that occurs in petrol engines when the fuel octane being used is too low for the engine's design. It rapidly causes high bearing loads and piston temperatures that can lead to major engine damage. It's been with us since the dawn of the internal combustion engine, but in those early days of very low output engines, it was at first just an annoying rattling noise coming from the engine.

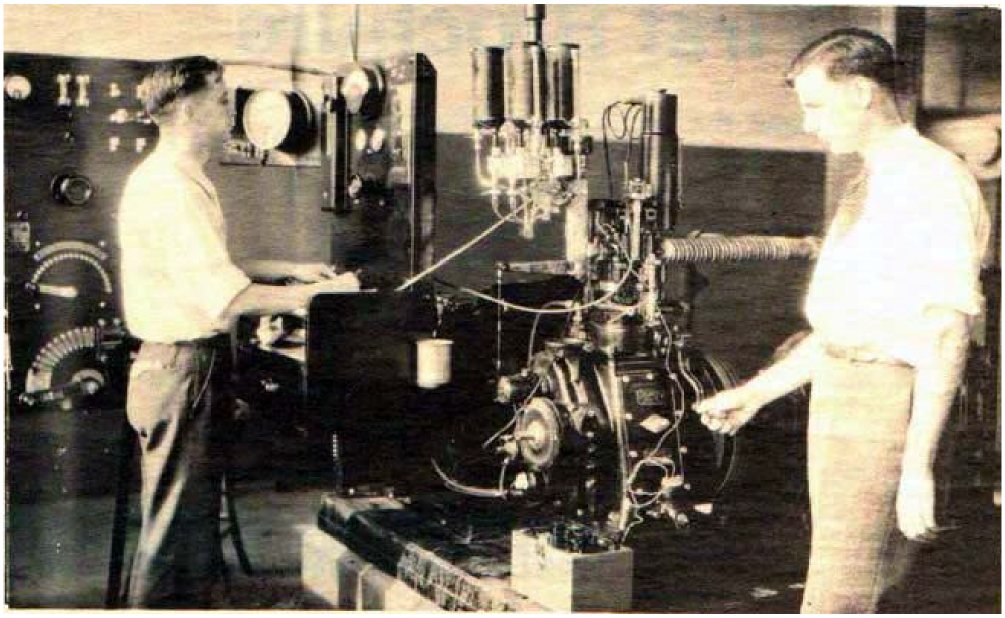


CFR engine and control panel

During the First World War there was a sudden increase in the need for higher output engines to power planes and tanks. The available fuels were very prone to detonation and caused many early engine failures, so some of the best scientific brains of the day concentrated on finding a cure. They soon discovered that petrol made from the crude oil from different regions of the world had very different detonation characteristics. Harry Ricardo in England and Thomas Midgely in the USA were two people who became famous for their work on fuels. Their discoveries lead to the use of tetra-ethyl lead as an octane booster and the use of laboratory fuels like iso-octane to rate fuels.

Chemical analysis of the fuel was too difficult in those days, and it's still not simple with over 200 different identifiable hydro-carbon compounds in what we call "petrol", so in the 1920's attention turned to testing fuels in special engines. The Cooperative Fuels Research (CFR) committee was jointly formed by automotive and oil companies to design the test engine. The resulting CFR engine was built by the Waukesha Engine Company in 1928 and is still used today, albeit with some modern extras like computerised control.

The CFR engine is a single cylinder, 600cc, 4 stroke engine with a compression ratio variable from about 4 to 1, up to as high as 18 to 1, while running. It uses a carburetor with several float chambers so that the fuel being tested can be quickly switched with the turn of a tap. The engine also has heaters to control the temperature of both intake air and fuel, and gauges to both monitor the engine and show when detonation is occurring.



Fuel octane testing in the 1930's. Operator on the left is observing the knockmeter (centre, top of panel) while operator at right is gripping the handle that moves the cylinder up and down to vary compression ratio.

The first test developed is today called the Motor Octane Number (MON) test. The CFR engine runs at 900 rpm, inlet air is kept at 38 degrees C, the fuel is kept at 150 degrees C and ignition timing is varied to match compression ratio. This test represents engines under high load, high throttle opening conditions. The fuel under test is run and it's knock or detonation characteristics at different compression ratios were noted. Then the test was repeated this time using a laboratory fuel, which is a mixture of just two compounds, N-heptane and Iso-octane.

N-heptane has an octane of 0 (zero) and iso-octane has an octane of 100. By varying the mixture an octane number anywhere from 1 to 100 is possible. When the laboratory mixture had the same knock characteristics as the test fuel, the amount of iso-octane used became the octane number of the test fuel. Thus a fuel, which knocks like 60% iso-octane, 40% n-heptane brew has an octane rating of 60. The highest octane theoretically possible is 100 (100%iso-octane), but there are fuels with octane ratings over 100. This done by using charts that allow the test results to be extrapolated past 100 according to how much compression it can stand over a 100% iso-octane brew. Strictly speaking numbers over 100 aren't octane ratings but "performance numbers" however, for convenience we just use octane.

Later it was discovered that some lightly loaded engines, like cars on relatively flat roads, could still get into detonation trouble even with fuels that performed well in the MON test, so another test was developed that used a similar CFR engine with different criteria. This test is called the Research Octane Number (RON). The CFR engine runs at 600 rpm, the inlet air temp is varied to match barometric pressure, but the ignition timing is fixed. This test better represents engines under part throttle conditions. The Research Octane number is usually higher than the Motor number for most automotive fuels.

During the 1960's another complication arose in fuels with a large difference between their Motor and Research octane numbers (called the fuel's sensitivity). This lead to trouble with some high compression engines on high speed roads, so in the early 1970's the AKI method was adopted in the USA. AKI is the average of RON and MON and is a better indicator of any fuel with a high sensitivity, when only one octane number is advertised. The reduce consumer confusion over different octane numbers, the USA passed laws so that AKI is the octane rating shown on pumps at petrol stations in that part of the world. Because of this it is also sometimes called the Pump Posted Octane Number.

Other versions of the CFR engine are used for aviation fuels (with supercharging) and for diesel fuel to get Cetane ratings. Today's CFR engine costs about US$120,000 and comes with computerised data acquisition to speed up testing and improve reliability. Modern computerised chemical analysis is also used for refinery quality control so that tests in the CFR engine are not required so often.

A mixture of old and new. Modern CFR engine control panel showing old style Knock meter alongside computerised control system.