An Overview of the new CITS Engine Technology.

Crankcase Independent Two Stroke

"Engine of Tomorrow."

For inventing this CITS engine technology, with two patents granted or in progress in over 50 countries, Basil van Rooyen was awarded a nomination in the **SAE**-A "2012 Automotive Engineering Excellence Awards"

Executive Summary

The CITS engine technology provides a proven basis for a superior petrol (or LPG) engine which is substantially lighter, smaller, smoother, and lower-cost, per kW, whilst **eliminating** the usual burning of the two-stroke's lubricant with the fuel, called total-loss-lubrication, and the associated exhaust emissions. Instead, CITS uses recirculated sump-lubrication like the four-stroke. It has been independently and successfully tested for proof-of-concept as a single-cylinder, and later as a more sophisticated water-cooled V-twin-cylinder **indirect** fuel-injected prototype. This test confirmed all that had been predicted, including:

- The functioning of the variable primary compression-ratio By-Pass valve. See https://youtu.be/hLj-hk61GzA.
- Increased efficiency from CITS' tripled primary compression-ratio, and superior pressure-chambers.
- Lubrication to the upper-cylinder.
- Mechanical and thermal soundness.
- 60% closer bore-axes now possible, giving proportionally reduced imbalance forces and smoother-running.

The CITS V-twin prototype start-up and running can be seen on http://citsengine.com.au/?page_id=320 which was witnessed by Dr. T. White of UNSW School of engineering, two Motec technicians (Ignition and Injection specialists), ex-Telstra electrical engineer M. Moore, the patent attorney and shareholders.

Like all two-strokes, to deliver optimal data, the CITS V-twin prototype must now be equipped and mapped with **Direct** Fuel-Injection (DFI) by internationally respected engine science specialists, and then be published in the journals which are read by the technical hierarchy of the motor industry. They receive so many patent ideas per year, that their extensive study and evaluation becomes impractical, forcing them into evaluating only independently published scientific data. Funding to provide that is CITS's strategy underway, with a formal capital-raising document available to investors on request. CITS Engineering PL represents a rare **investment opportunity** in a convincing technology. We also invite any direct presentation opportunity with major motor manufacturers.

Plug-in **H**ybrid **E**lectric **V**ehicles (PHEV's), are the transition format to the electric cars of the future. They are like an **E**lectric **V**ehicle (EV) but also have a back-up combustion engine, to charge the batteries on the run without driver intervention, when batteries run low. This eliminates range-anxiety, by giving the PHEV the same range as today's cars, whenever needed, and eliminates the traffic chaos that could ensue with flat batteries, resulting from headwinds, hilly terrain, heavy loads, hot weather, ageing batteries or hard driving etc. The PHEV can travel average daily commuting (about 50km) on **much smaller** batteries, with **zero** fuel or emissions, and can be charged overnight on domestic outlets, on much cheaper **off-peak** power. **No waiting for 40 minute recharging at fast charging points!** Leading manufacturers all have these PHEV's either in the pipe-line, or in production, as is the case with BMW, Mitsubishi, Volvo and GM. PHEV's can reduce the world's auto fuel-consumption and emissions by 90% - the other 10% being the average use of petrol for travel **beyond** average daily commuting on batteries. Because 80% of the 80m cars made today, are in the $10,000 to $15,000 range and PHEV's and EV's start at $40,000 they are **irrelevant** as an affordable game-changer for the global city smog problem. And the major auto-growth expected from Asia, with

families riding on mopeds aspiring to small cars, will add another 30m estimated p.a. within 10 years. To reverse the daily growth in pollution and smog, EV's and PHEV's at today's mass-market prices are critical and essential.

The output of the typical small family car's **four-cylinder** engine today, is available from just **two-cylinders** of the V-twin CITS engine, at **well under half** the cost, weight and bulk. And the CITS technology allows it to be the smoothest running V-twin by over 60%. This makes it the ideal choice for the PHEV back-up engine, where at sweet-spot constant rpm, it can be super-tuned and best emission-controlled, and advantage taken of its ultra-low cost, weight, friction and bulk. This will help reduce the PHEV cost, together with cheaper batteries in the pipeline, and in-wheel electric motors, to bring affordable personal transport, even to the most smog-polluted cities on earth, with fastest growing car markets.

CITS technology also applies to the industrial equipment market, such as portable water pumps, and hospital and home generators. The CITS V cylinder format can any number of cylinder pairs, such as say a V8 engine of 10 litres, with over 1000 kW for hospital stand-by electric generators. For yet another market - recreational craft - the CITS's recirculated sump-lubrication and shorter V-twin crankshaft and plain shell crankshaft bearings provide significant cost, weight, emission and balance benefits for manufacturers and owners.

The CITS V-twin engine is much more than a new two-stroke with sump re-circulated lubrication, which **eliminates** the usual total-loss-lubrication. It uniquely also embodies:

- A patented space and cost-saving, **low-resistance patented pivoting inlet valve**, nestled neatly within the perfect geometry between the opposing V-twin cylinders, and **self-driven** by their alternating pressure cycles.
- An integral patented **By-Pass** valve allowing the best of both worlds in economy, emissions and power, by replacing the throttle and its down-stream pumping losses, and
- Providing a **variable** primary compression-ratio, from significantly higher and lower than previously possible, and mappable for optimising power and economy and emissions at all throttle conditions.
- The three-times higher primary compression-ratio (found below the two-stroke's piston) available with CITS, provides a proportionately higher **de-compression-**ratio for more powerful and complete induction under time restraints, and thus greater efficiency and power.
- This higher primary compression ratio also allowing a delayed exhaust opening and reduced waste of combustion pressure from the piston, providing a further gain in efficiency and economy, and in **reduced exhaust noise**.
- 70% lower imbalance-forces, proportional to a typically 70% shorter crankshaft possible with CITS, between twin-cylinder axes, for lower cost, weight, and friction, and smoother running.
- Plain crankshaft bearing-shells, instead of the normal two-stroke's expensive roller-bearings and their complex fitment to multi-cylinder crankshafts.
- Significantly reduced HC-emission traps in its unique CITS piston and ring assembly, made possible by the **elimination of side-thrust** on its piston-head, ensuring less of these unburnt fuel emissions.
- Improved fluid-dynamics, from the CITS engine's inducted charge being **isolated** from the usual maelstrom within the crankcase, and instead entering the tranquil CITS pressure chamber below its piston, for more efficient induction, and transfer through the transfer ports – a flow which uniquely is never halted, reducing the stop-start flows in the non-CITS two-strokes' transfer ports – a significant kinetic saving .
- In addition to the well documented *squish* employed **above** the piston in the combustion chamber, there is **unique squish below** the CITS piston as it approaches the thimble beneath it. This squish causes a powerful expulsion of trapped gas, which is harnessed by deflection, to boost the flow through the transfer ports.

These eleven major benefits are covered in the following pages. They are based upon self-evident basic physics, which emerged synergistically along the development journey of the CITS V-twin technology. The final stage now is to scientifically quantify and publish the benefits, in emission, specific fuel-consumption, and output data, when optimised with **direct fuel-injection**, in order to commercialise the technology through royalties. This final step is awaiting funding via a formal capital-raising share offer now available to interested investors.

Contents Page

1 Abbreviations and Acronyms

BDC Bottom dead centre

BMEP Brake mean effective pressure

CITS Crankcase independent two-stroke

CC Combustion chamber

DCR De-compression-ratio

EV Electric vehicle

IC Internal combustion

NTS Normal two stroke

PC Pressure chamber

PCR Primary compression ratio

PL Pty. Ltd.

PHEV Plug in hybrid vehicle

RPM Revolutions per minute

SAE Society of automotive engineers

TDC Top dead centre

TMI Too much information (-:

TLL Total loss lubrication

TP Transfer port

2S Two-stroke

4S Four-stroke

2 Background

2.1 The Normal Two-Stroke (NTS)

An animation of the NTS can be seen on http://www.animatedengines.com/twostroke.html

These engines we often think of as the lawn mowers' carburetored smoking polluting engines, but they are also the sophisticated multi-cylinder **direct fuel-injected** two-strokes found in leading outboard motors. Unlike CITS however, they all still induct **into the crankcase** under the rising piston and mix oil with the petrol (see Figure 1).

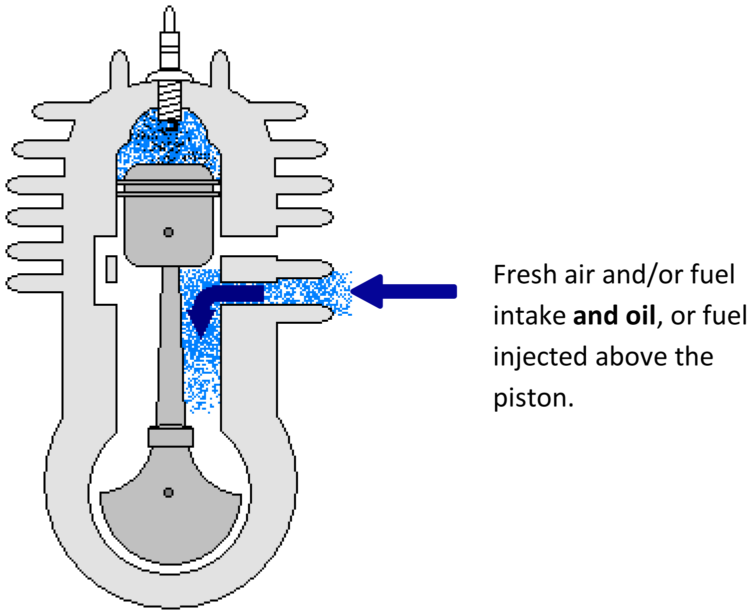

Figure 1 Normal Two Stroke inducting into the crankcase.

After hitting the maelstrom of spinning gas, the **oil-laden** charge is then transferred, via the Transfer Ports, from the crankcase to the Combustion Chamber (CC), when the descending piston opens them just after opening the exhaust-port, as shown in Figure 2, chasing out the simultaneous exhausting of the combusted charge.

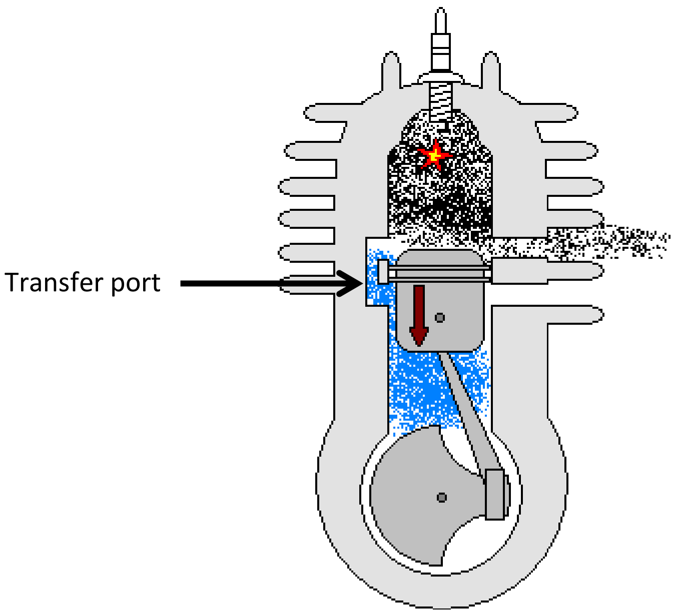

Figure 2. The Normal Two Stroke transfers the charge loaded with the lubricant from the crankcase into the combustion chamber via the transfer port during exhausting.

Thus in the NTS, the common crankcase-sump lubrication found in today's cars cannot be used, because pressurised oil spinning off the crankshaft would be inducted and consumed. So instead, **excessive oil** is needed to be **mixed with the fuel**, (**total-loss-lubrication**), or sprayed onto the roller bearings of the crankshaft, causing extra HC emissions and oil in the exhaust. This marginal lubrication demands expensive roller bearings with their complex fitment issues must be used in place of the more usual pressure lubrication and simple split-shell bearings.

2.2 Advances in technology for the Normal Two Stroke

Advances in direct fuel-injection and electronic engine management have improved performance and emissions of NTS's dramatically. This can be seen in their success in today's recreational engine markets where advanced 2S engines (including the Evinrude ETEC, and Mercury OPTIMAX outboard motors, and the Rotax 800H) out-perform 4S competitors in many published comparison tests in economy, maintenance, and power-to-weight ratio. Although EPA 3 (recreation market) emission-capable – the massive oil to petrol burning exceeds EPA 5 road limits.

2.3 Normal Two Stroke (NTS) limitations overcome by CITS

Despite the advances mentioned, NTS engines still face emission problems from burning their lubricant, mixed with the fuel, known as **Total-Loss Lubrication (TLL**). For example, two-stroke outboard motors are **banned** from use on all EU and UK many other countries' freshwater lakes. This is because oil mixed with the fuel, causes emissions with oil residues on the water from the exhaust. This is also a reason why NTS engines have not found their way into the auto market, where EPA5 emission regulations are more stringent than in the recreational market.

An associated problem with normal two strokes is that they need individual crankcase voids per cylinder, to induct and compress alternately in each. This causes the cylinders to be set well apart, causing a much longer crankshaft than a compact V format allows, and increases the "rocking moment" imbalance forces proportionately (see pg 16).

With CITS technology, these lubrication, emission and rough-running issues are all **eradicated.**

3 CITS Technology plus its patented valving

3.1 General Attributes.

Simplified **animations** of the technology can be seen on https://youtu.be/hLj-hk61GzA . The actions depict how both high and low power situations are uniquely optimised by CITS patented **By-Pass valve** technology.

The CITS engine technology provides the basis for a lighter, smaller, smoother, lower cost, engine per kW, with sump lubrication. It has been independently and successfully prototyped for proof-of-concept as a single-cylinder (see section 0), and as a V-twin has recently had its first start-up, confirming the way forward.

The following 4 points provide the **incontestable evidence** that CITS technology, combined with the dramatic **established** advances in today's leading NTS recreational engines (see section 15), CITS has the attributes to be the Internal combustion engine for the transition decade/s that lie ahead, for portable and stand-by industrial engines and for Plug-in Hybrid Vehicles, and before global **renewable** energy becomes an affordable reality:

- High two-stroke power, with low weight, cost, emissions, fuel-consumption and maintenance.
- Compact crankshaft length. CITS allows the first compact V-twin two-stroke, about 70% shorter.

- 70% Reduced CITS V-twin engine vibration, allows the reduced cost, weight and size of just **two cylinders** to replace the four and three cylinder current four-strokes in PHEV autos.
- Massively reduced production cost and weight, with about 80% fewer parts and less cylinders.

3.2 Power, economy and reduced emissions

The CITS technology affects nothing in the advanced NTS **above the piston at BDC,** mechanically or architecturally, and thus can claim the best of the NTS's recognised efficiency in combustion, power, and economy as a **starting point**. It is from that lofty platform, that the CITS quantum leap starts, with its mechanically simple, but dynamically subtle, two-stroke developments which lurk **below, around, and within,** the CITS piston. By efficiently separating the pressure-chamber (PC) below the piston from the crankcase, the compact V-twin becomes possible, with dramatic reductions in vibration (see section 12), and the emission burdens from total-loss lubrication are **eliminated.** At the same time**, this V geometry allows the perfect placement of the CITS patented Pivot and By-pass Valves, for optimising their potential.** This is covered on page 15 and for advanced technical readers, see pages 27-30 for further coverage of the CITS fluid-dynamics, and please see the self-driven inlet valve in action on this same video: https://youtu.be/hLj-hk61GzA

Engine bulk, cost and weight.

A compelling benefit of the CITS engine is its small cost-to-power ratio. But the space taken by an engine in a vehicle is space that could be used for occupants, or luggage, or improved aero-dynamics. And the smaller it is, the lighter it is, and the lower is its cost. A 100 kW CITS V-Twin engine, as an example, is well under half the bulk, weight, friction and cost of a typical 100kW 4 cylinder 4 stroke engine found in today's cars, as illustrated in Figure 3 below. Engine bulk and cost, has become more important, with the recent and exciting development of the ***Plug-in hybrid Electric Vehicle (PHEV)***. This offers daily average commuting, about 50 kms, on batteries, with **zero** fuel and emissions, being chargeable ***overnight*** parked at home, ***on off-peak power***, when the generators cannot switch off, and so ***less emissions*** are caused at source. At the constant rpm of the simple range-extender (stand-by) IC engine, the emissions of the CITS two stroke can be most effectively controlled. No other engine per kW has yet matched these combined CITS design advantages for the PHEV application – surely the auto engine's format of the future.

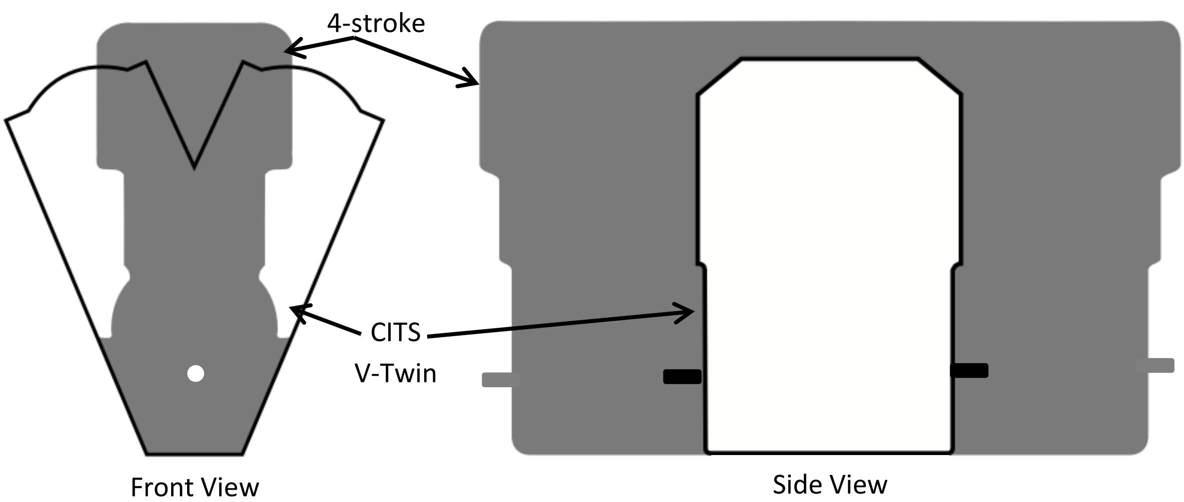

Figure 3 Size comparison of compact CITS V-Twin and current average 4 stroke car engine of the same power output.

4 The future of IC engines and the market for CITS

Although electric vehicles (EV's) are still making headlines in the media, industry commentators (an impressive and extensive list is available) agree that the next two decades will see a stand-by combustion engine charging batteries for an electric motor, called Plug-in Hybrid Electric Vehicles (PHEV's). These can provide about 50km (average daily) electric commuting, with **zero** fuel consumption and emissions, and well under 4L/100 km, for longer trips. This is one of the giant markets at which the CITS engine is aimed, usurping it from the more expensive and heavy four-stroke. Many other markets will also benefit. With range-limited EV's like the Tesla still carrying 300 kg to 900kg of rare-earth batteries, and the Audi E8 no less than 550, today's 80 million cars produced annually as EV's, would require over 70,000 tons of batteries **per day**! This unfeasible ramping-up of battery production, the massive cost of their replacement every ten years or so, the carbon foot-print from mine to showroom, the carbon emissions from dirty coal-fired power for some decades to come, and fast charging infrastructure at every home and every 100kms along every road on earth to fast-charge them as needed, and the unaffordable retail price penalty, are clearly longer-term challenges to the EV. The PHEV is an **immediately realisable** transition, already appearing in showrooms, allowing average daily commuting on batteries on **zero fuel use or *emissions**, and with the security of a stand-by IC engine. The smaller PHEV battery pack is under a third of the cost and weight of the average EV battery pack - allowing **overnight** charging on***off-peak power** at home. This milder on-the-run and overnight charging regime, and can **double** battery life. Thus the PHEV lowers the 10 year EV's battery demand and cost by up to a remarkable 75%. Why has the PHEV not become a global game-changer? **Affordability**! The PHEV like the EV, today costs about 2.5 times the cost of a current comparable petrol-engine car. **Only** with savings from all these three developments - **a)** battery technology in the pipeline, **b)** the electric in-wheel motor like the www.in-wheel.com and www.proteanelectric.com , which eliminates the cost and weight of an auto's **entire transmission and brakes**, **PLUS c)** the CITS V-twin back-up engine, can **combine** to bring a PHEV to the showrooms at the petrol equivalent's price – and be a global mass-market changer. CITS's low-cost and weight per kW, is critical as a key contributor to greening the mass auto markets. For industrial applications, the CITS V-format can allow a V12 for example with 800kW.

5 Entry restrictions into the motor industry

Why have car manufacturers not yet embraced CITS technology?

As mentioned earlier, motor manufacturers receive many patent ideas per year, and each demands extensive legal, mechanical, production and marketing study, for evaluation. As this is impractical on the hundreds they receive, they must rely on their in-house R &D, unless independently and scientifically proven technology is published - which we are on course to do. Also, the "Not Invented Here" syndrome is still alive and well.

6 Research and development requirements for CITS and expected costs

Initially independently and successfully tested for proof-of-concept as a single cylinder, now a CITS water–cooled V-twin has run successfully, on **indirect fuel injection**. See this on http://citsengine.com.au/?page_id=320.

It must now go to a leading engine-facility, for **direct fuel-injection**, and its data published by specialists in this science, who are recognised by the motor industry. These results will appear in technical media, which is read by industry technocrats, in order to market the CITS intellectual property (patents) to them on a royalty basis. Funding for this final stage to commercial completion is sought through an AUD$4m capital raising by a share offer. A formal Information Memorandum (IM) is available to interested investors. This small investment is due to the 6 years of development and design work completed, as well as some federal government incentives, and cost-saving measures, which in no way detract from the rigour of the project. This IM also lays out the estimated scientific, legal,

administrative, and marketing costs, and details the investment risks. Multiple returns for success on the investment are forecast. The project will be undertaken in stages to further limit investor risk.

The current running CITS V-twin prototype is based on 3D CAD design work, combining CITS technology (with its below-piston pressure chamber), built upon the crankcase of the Suzuki V-twin 4-stroke, and with proven Rotax above-piston porting and architecture, using CITS unique pistons and crankshaft, and on interim carburetion. Now the stage is set for direct fuel-injection. This will combine proven benchmark-setting power (115kW from 800ccs!), economy and EPA 3 emissions of the remarkable Rotax 800h (see the SAE article in Section 15, page 22), with added CITS's attributes, being a compact, better-balanced, V-twin two-stroke, and with a three-times higher Primary Compression-Ratio, its combustion unburdened with any total-loss-lubrication, on "clean" petrol, and recirculated lubrication. The required direct-injection development and scientific emission data must be completed by eminent contractors, such as Orbital Engineering in Perth, or by Ficht of Germany, recognised world leaders in this field, along with the optimisation of the patented Pivot and By-pass valves, each offering further cumulative or separate contributions to the efficiency of the CITS V- engine.

This will ensure a low-cost, smoother, lower emitting two-stroke, which is more capable and efficient as a PHEV range-extender or for industrial machinery like generators and water-pumps. The constant rpm feature possible in these markets, ensure the best opportunity of complying with the rigorous emission regulations, which currently exclude lubricant-burning NTS's from road use, and from EU, UK and other fresh water marine use.

Once data is captured, and if compelling and technically-disrupting as expected, the Intellectual Property will be marketed globally on a royalty basis to the major engine manufacturers, through the media, the Society of Automotive Engineers (SAE) and personal presentations.

7 Funding and risk

Funds are being raised via a private share offer, for which a formal **Information Memorandum** is available. Exceptional expected returns for success are laid out therein for the life of the patents. On page 22 is an internationally respected, independent expert appraisal of the claims made, whilst the intellectual property strengths of its PCT patents have been determined by patent attorneys, and details are tabled on page 10. These patents, and the high probability of success in the global markets for CITS, provide an excellent low-risk, high-return venture capital proposition, with the extra bonus of doing something positive towards dramatically reducing the increasing smog issues in cities, and emissions in the air we all breathe, as well as towards any global-warming threat, and the conservation of oil for the airline industry.

Mechanical issues such as CITS piston cooling and lubrication considerations (see sections 13.2 and 13.3) have been successfully prototyped on a single cylinder, and independently dynamometer-tested for short term mechanical durability, cooling and lubrication, running on oil-free petrol, and under the arduous thermal loads of air cooling. Further successes achieved on a more sophisticated V-twin prototype confirmed the three major predictions, and together with the current and proven technology of the latest NTS's, minimises any unknown risks.

Established current NTS outputs, plus the CITS V-twin achievement of **eliminating** TLL, a higher primary compression-ratio, and dramatically reducing V-twin vibrations, provide a high level of certainty in achieving a smooth-running engine of lowest production cost per kW - something sought by all in the engine industry – and allow us to move further into the realm of the optional Pivot and By-pass valve development, and evaluate these promising and exciting innovations as the final stage proceeds.

CITS patent work is handled by Wallington-Dummer – Sydney patent attorneys. See section 8 for details.

8 Patent progress Schedule as at: 17/10/2016

"Patent Family" legend	Status Legend	Colour key
PCT-1 =Improvements in two-stroke engines PCT-2 = Two stroke engine porting arrangement	1 = Filed 2* =Exam requested 2 = Exam report issued 3 = Accepted for grant 4 = Patent granted	Yellow: cases accepted for grant or granted Blue: cases pending but likely to be accepted by November 2016 Green: cases pending with examination estimated to be delayed by up to two years due to Patent Office backlogs

File	Country	Patent Family	Application Number	Filing Date	Status
092050	Australia	PCT-1	[2009238281]	16/11/2009	4
102077	China	PCT-1	[201080060247.2]	16/11/2010	4
102080	Japan	PCT-1	2012-538148 [Patent No. 5844271]	16/11/2010	4
102081	South Korea	PCT-1	10-2012-7015139 [Registration No. 10-1581994]	16/11/2010	4
102082	Mexico	PCT-1	MX/a/2012/005633 [Patent No. 330760]	16/11/2010	4
102084	United States	PCT-1	13/509888 [Patent No. 8,683,964]	16/11/2010	4
102078	Europe	PCT-1	10829370.5	16/11/2010	2
102076	Brazil	PCT-1	1120120113747	16/11/2010	2*
102079	India	PCT-1	4801/DELNP/2012	16/11/2010	2*
102083	Thailand	PCT-1	1201002243	16/11/2010	2*
112097	Mexico	PCT-2	MX/a/2013/005193 [Patent No. 339633]	11/11/2011	4
112103	United States	PCT-2	13/884273 [Patent No. US 9,334,789 B2]	11/11/2011	4
102029	Australia	PCT-2	[2010241402]	12/11/2010	4
112096	Japan	PCT-2	[2013-538005]	11/11/2011	4
112098	New Zealand	PCT-2	[611455]	11/11/2011	4
112100	Russian Federation	PCT-2	[2013126883]	11/11/2011	4
112092	China	PCT-2	[201180064849.X]	11/11/2011	4
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112091	Canada	PCT-2	2817637	11/11/2011	3
112093	Europe	PCT-2	11840243.7	11/11/2011	3
112101	South Korea	PCT-2	10-2013-7014434	11/11/2011	2
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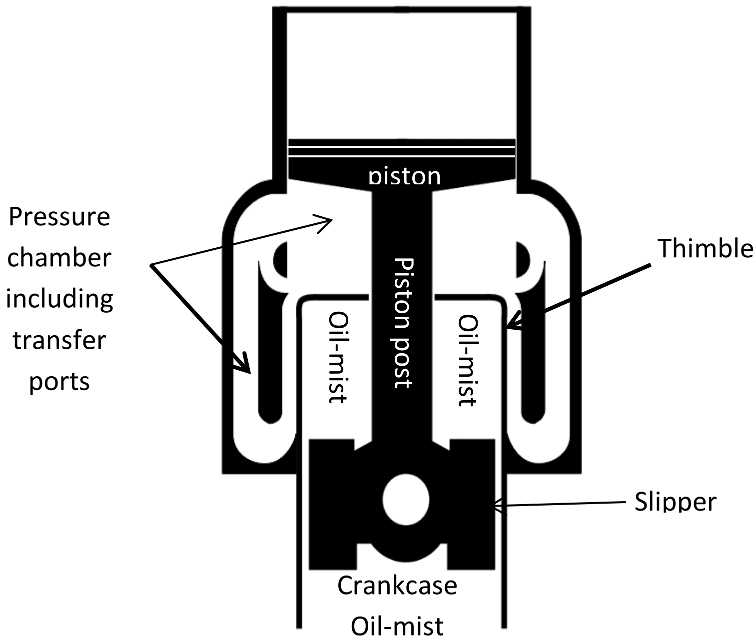
9 The Increased Primary Compression Ratio (PCR) of the CITS vs. the NTS.

(For the more technically minded, also see the brief synopsis on CITS fluid-dynamics in section The NTS (normal two-stroke) inducts under the rising piston, and then, compresses this charge within its voluminous crankcase during the piston's down-stroke, limiting a maximum practical Primary Compression Ratio (PCR) to under 1.3:1 as shown in Figure 1 in Section 2.

The CITS engine, on the other hand, isolates the NTS crankcase void without changing anything in the NTS architecture above the piston, by way of an annular moat around the lower "thimble" which acts as a **pressure chamber** (PC) as shown in Figure 5. This subtracts the volume of the crankcase, from the PC, thus increasing the highest practical **Primary Compression Ratio (PCR)** by a large factor.

As substantiated in Professor Gordon Blair's Two-stroke reference work, "The Basic Design of the Two-Stroke Engine" pg. 232, 5.2.3. , the highest practical PCR is limited to under 1.3 by the volume of the crankcase voids. He further established that the engine's output increased with every possible increase in PCR beyond this practical limit he was able to reach by temporary means.



The crankcase is separated from the Pressure-Chamber by the thimble

Figure 4 CITS schematic showing pressure chamber
Note: inlet and exhaust ports are omitted for simplicity

In the present iteration of the CITS prototype engine, the PCR at 1.6:1, is **three times** higher than that of the Rotax 800 upon which it is based – and far higher than what Prof Blair could attain. That is used as a starting point, for transfer port design and other trade-offs, until testing indicates the optimum PCR on future prototype iterations.

A high primary compression-ratio incurs fuel consumption penalties at throttled conditions on the NTS – but not on the CITS engine, due to the patented CITS **By-Pass valve** (See Section 11). This valve turns the disadvantage to advantage, not only reducing the effective PCR to the optimum lowest for idle, but allowing the best of both worlds for the first time – an variable and mappable PCR from idle to full power. The action is also clearly shown in action on https://youtu.be/hLj-hk61GzA and is shown in Figure 24, pg.29, neatly installed in the prototype.

9.1 Below-piston porting

The charge flowing through the Transfer Ports (TP's) is boosted by re-directing the squish-forces created between the piston, as it approaches bdc, and thimble, via the short upper-squish ports shown in Figure 5.

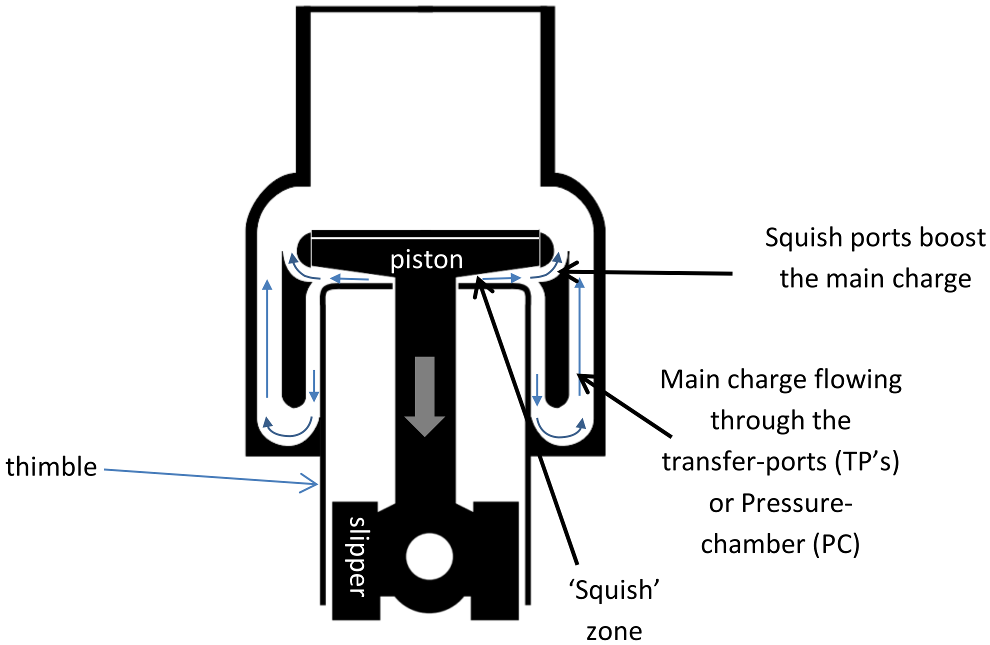


Figure 5 Squish ports exploiting squish forces

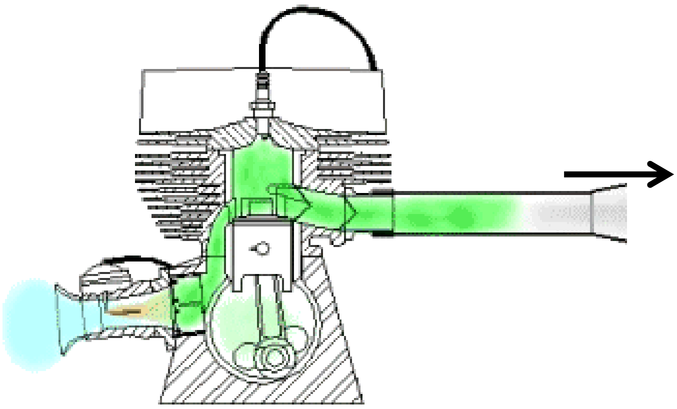
9.2 Air transfer efficiency from below to above piston.

In the NTS, the inducted fresh charge enters a maelstrom of spinning air within the crankcase, needing velocity and direction changes to enter the Transfer Ports (TP's). By contrast, the CITS air is instead inducted within the more tranquil Pressure Chamber and the TP's, thus poised for more immediate and efficient transfer. Less work is needed by the engine in transferring the charge via the CITS PC than is needed via the NTS crankcase.

9.3 Exhaust tuning considerations.

NTS engines rely on exhaust scavenge tuning by harnessing the out-rush of exhaust gases from the CC, which then lowers the pressure there-in, to pull fresh air through behind it as seen in Figure 6 pg. 13. CITS will reduce or eliminate the need for this bulky exhaust system.

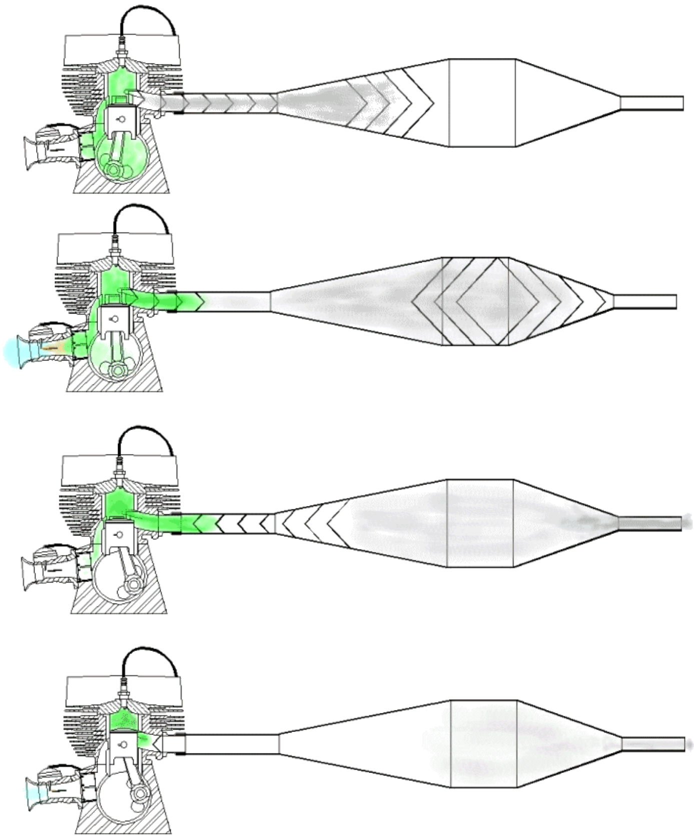
(An animation of the NTS can be seen on http://www.animatedengines.com/twostroke.html)



The rush of exhaust gases pulls through fresh air from the Transfer Port, and in doing so reduces pressure in the Combustion Chamber (CC), but at a loss of pressure on the piston. CITS will reduce or eliminate this procedure.

Figure 6 NTS normal exhaust tuning to exploit "scavenge" to pull through fresh air from the intake, and "stuff" some back.

In the system described above, the lower residual pressure in the CC reduces the mass of the charge of air at entrapment (exhaust closure) and thus loses potential power. By tuning the pressure waves in the exhaust, some extra fresh air drawn into the exhaust can get "stuffed" back into the CC just before entrapment, greatly boosting the mass of air and power as seen in Figure 7.



Descending piston opens the exhaust port and transfer ports.

Exhaust outrush lowers engine voids' pressure to open the inlet reed valve on reaching bdc.

Rising piston closes the transfer ports, whilst exhaust pressure waves "stuff" back fresh charge from the exhaust pipe.

As the rising piston closes the exhaust-port, the charge is com-pressed by the piston for final ignition and combustion near to tdc.

Figure 7 Pressure waves from the exhaust 'stuff' the fresh air back into the piston chamber

The greater the extent to which this tuning is exploited, the **narrower** is the **rpm range of power increase**. For the Range-extender application which can use constant rpm, this represents an option, if the trade-off against the bulky

exhaust is warranted. In other applications, CITS fluid-dynamics reduce **or eliminate** the need for such exhaust tuning, allowing a wider power band.

No changes are needed to normal engine manufacturing machinery and methods for the CITS engine. In addition to the known production economies of a two-stroke vs. a four stroke, there are a number of CITS cost benefits in addition to those savings in the lower cost valves in sections 10 and 11.

- By CITS isolating the crankcase, the economies of a simple and shorter crankshaft and plain shell-bearings with pressurised lubrication found in a 4-stroke, can at last be utilised on a normally inducted two-stroke, **eliminating** the costly needle roller bearings and the complex crankshaft fitment which the NTS demands.

- The existing supplier relationship with the engine manufacturer of ancillary equipment is maintained, there being no changes to ignition, injection, exhaust, water and oil pumps etc.

- On multi-cylinder applications, CITS **eliminates all** expensive, complex sealing required between crankcase voids of individual cylinders of the NTS to maintain the pressure cycle of each individual cylinder's crankcase void.

- The patented pivot inlet valve and By Pass valve are combined in a small unit shown in Fig 22 pg 25. It has a fraction of the bulk and cost of the typical throttle and reed valves,

10 The patented inlet Pivot Valve

This is one of our two patented CITS valves. Note that **neither are driven** by the engine mechanically. The **self-driven** pivoting inlet-valve shown here, in Figure 8, replaces the usual two-stroke's flow-restrictive tension-closed reed valve, and no longer is the induction flow disturbed through the bulky reed block, but flows smoothly velocity, as seen in Figure 9, pg. 15.

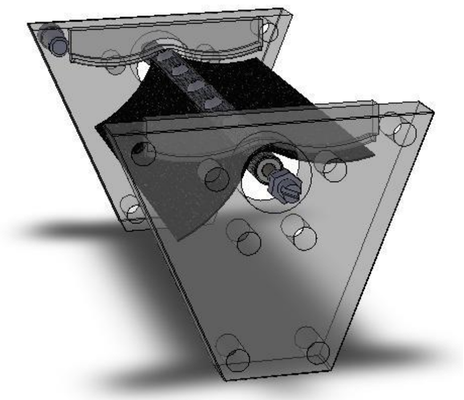


Figure 8 Components of the Pivot-valve, showing the rigid interconnected petal

The alternating induction and compression under the CITS V- twin pistons, and the perfect geometry between them, enables a novel pivoting inlet-valve. It is free-acting, and driven by air, its two petals being rigidly **interconnected** between each cylinder's inlet passages, so that the alternating pressures of the compressing piston and the inducting piston, drive the petals in concert as shown in Figure 9 and in **animation** on http://citsengine.com.au/?page_id=349 . See ***views and sections*** of www.citsengine.com.au for bulk comparisons of the reed vs the pivot inlet-valves. See also photo of it installed on the CITS V-twin prototype in Figure 22 pg. 25.

The Pivot-valve's rigid dual-petal flips (pivots) from side to side, driven by the alternating pressures of each cylinder. Here piston B is compressing below it, closing the dual-petal, while piston A is rising and inducting (sucking) the other side of the petal open.

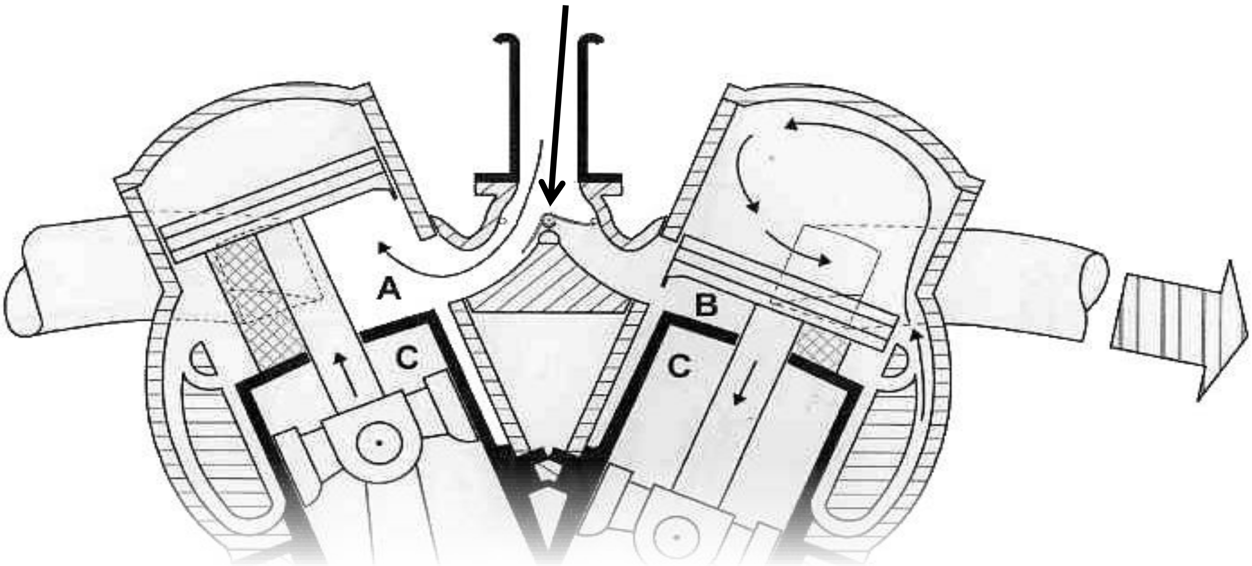


Figure 9 Pivot Valve in CITS V-Twin

The prototype has shown that its petal-tips can pivot at above the 6500 rpm maximum intended on the V-twin project. This has the exciting potential to increase CITS efficiency yet further. It can be seen installed on the prototype in Figure 22, pg 25.

It may be found that the constant inlet gas velocity at higher rpm, the Pivot Valve's ram-tube tract becomes a self-acting one-way valve at constant rpm, and that the pivot valve can have its full arc of travel **reduced or eliminated** at maximum power. A version of the valve has been developed to exploit this exciting possibility, with the petal lowered to the bottom, being wide open to both cylinders. This will allow any rpm without affecting petal-life and allow still greater flow on induction.

11 The Patented By-Pass Valve

The By-Pass valve

This is fitted beneath the pivot valve, and when **closed** (as shown), the alternating pressures below the pistons are independent. When rotated **90 degrees**, it opens so alternating pressures below the opposing pistons are in full communication, allowing them to short-circuit, reducing the nominal PCR to zero. See this video https://youtu.be/hLj-hk61GzA

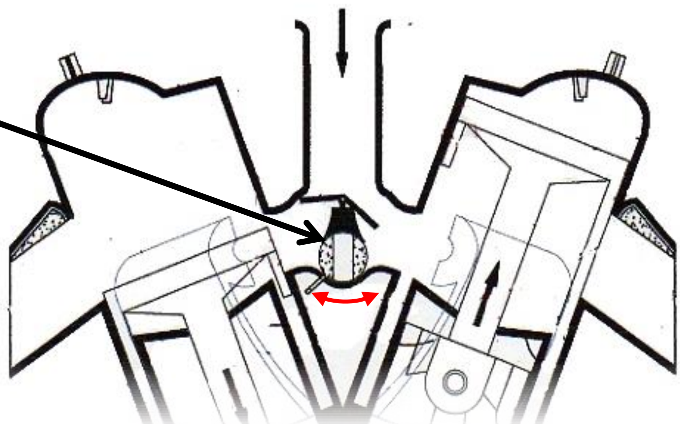


Figure 10. The patented By-pass Valve

The valve can also be seen installed in Figure 22, pg. 25.

Note in Figure 10, pg. 15, how by progressively opening and closing the valve allows any proportion of short-circuiting between opposing Pressure-Chambers, thus varying the fresh charge intake, and thus power, instead of a throttle.

Elegantly, it also effectively reduces CITS's high PCR (primary compression ratio) at those light-throttle conditions when a **lower PCR** offers fuel consumption and emission advantages. Thus this patented innovation for our CITS engine is a scroll valve opened and closed by **the accelerator pedal** that replaces the throttle for the engine's power control. By adjusting the PCR optimal to the engine power, it achieves the best economy at all power conditions – **another CITS first.** This is seen in animation on http://citsengine.com.au/?page_id=349

12 Engine Balance Considerations

The unique compactness of the CITS engine leads to greatly reduced vibrations and improved balance, allowing a V-twin cylinder engine inherently smoother than ever realised before. Nothing reduces engine production costs, friction, size, weight, and fuel consumption, as effectively as reducing the **number of cylinders**. In excess of the 90 kW output in the majority of the world's 4-cylinder cars is easily available in a twin–cylinder NTS, but the imbalance and the emission problem has restricted this option mainly to the recreational markets - **until now**. A CITS V-twin **dramatically** reduces the imbalance forces of parallel and V-twin-cylinder arrangements, both 2 and 4-stroke **for the first time**. Twin-cylinder engines would be seen more widely in small cars had they not been burdened with large imbalance forces, causing rough running.

Illustrated below in Figure 11 are the comparable major imbalance forces from the two most common twin-cylinder engines today versus those of the CITS V-Twin. This will be a compelling attraction to all in the small to medium auto market, allowing a twin-cylinder, with compelling reductions in production-cost, weight, friction, fuel economy and emissions per kW.

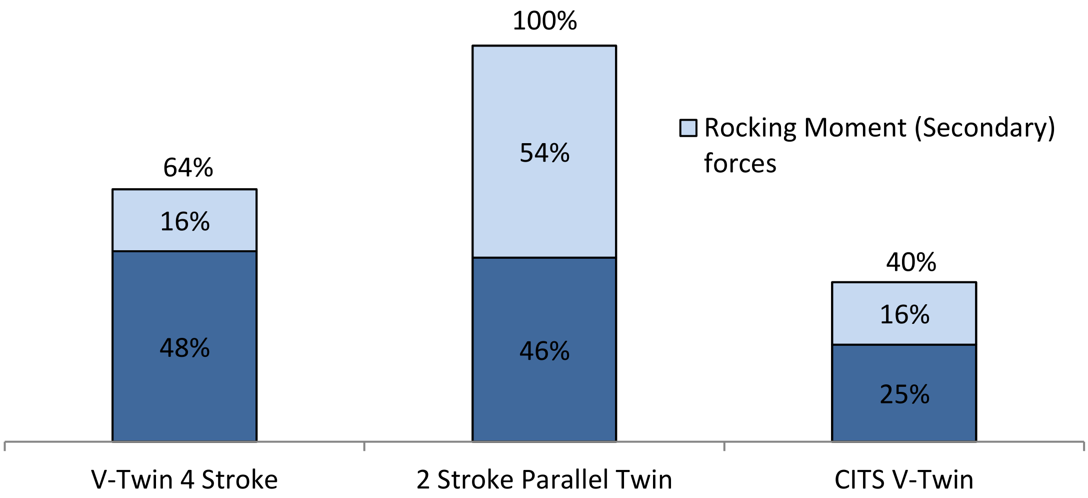


Figure 11 Illustration of comparative imbalance forces in twin-cylinder engines shown

On the NTS twin, which must have fully separated cylinders with individual crankcases and allow space for sealing the crankcase voids between them, it is burdened with a long crankshaft with equally distant ***opposing counterbalances***. These face ***opposite*** directions at ***mid-stroke***, with no opposing pistons, causing a severe rocking couple, which is proportional to this distance (see the typical parallel twin crankshaft pictured in Figure 13 pg 17). CITS instead, allows the two-stroke to be a ***compact*** V-twin. As illustrated by Figure 12 pg 17, this enables a 70% shorter crankshaft between cylinder axes, and the NTS twin secondary rocking couple is reduced commensurately.

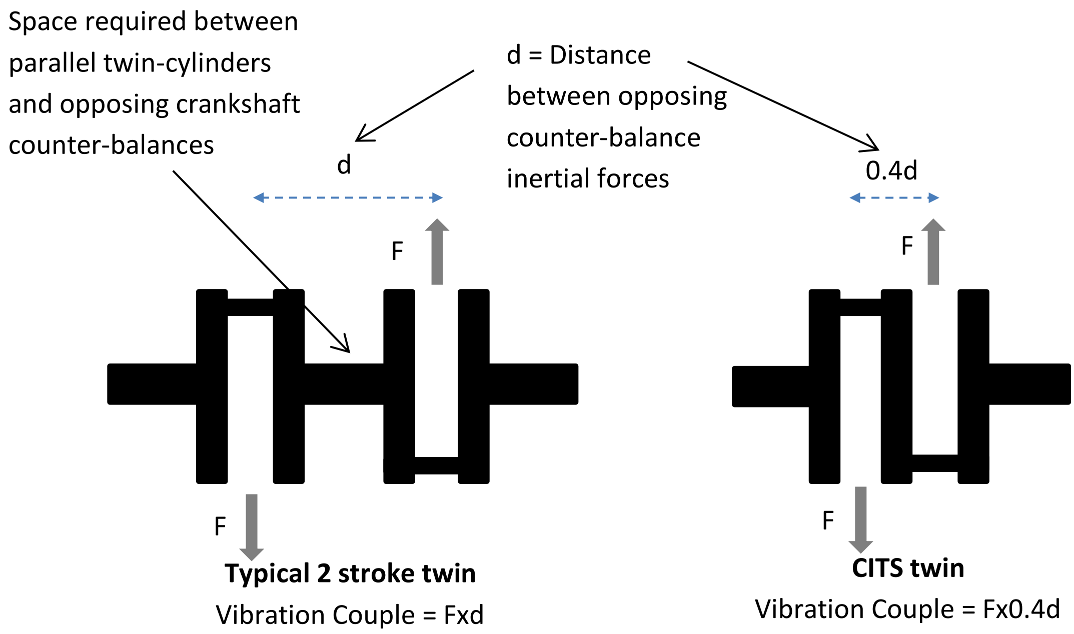


Figure 12 Comparison of crankshafts between typical 2 stroke twin and CITS V- Twin

On the 4 stroke V-twin, both pistons go to TDC ***together*** or close thereto, **combining** their inertial forces, thus requiring a heavy counterbalance, which of course is un-opposed by the reciprocating masses at mid-stroke (See the typical Suzuki V-twin in fig 16 pg. 18.) Because the CITS pistons travel ***opposingly***, they significantly **compensate**, **rather than combine** their reciprocal forces at TBC and BDC. So much so, that the CITS crankshaft at optimal balance has a counter-balance factor of 29% of reciprocating weight, vs. the usual factor of over 50%.

The length of the typical NTS twin's crankshaft can be seen in Figures 14 and 15. Note the great distance between its opposing crankshaft's counter-balances will increase their opposing forces when the pistons are at mid-stroke, and when there are no reciprocating masses opposing the counter-balances. This causes the rocking-couple described earlier. This couple is reduced by about 60%, being the shorter distance between CITS cylinders axes as shown in Figure 12. The same applies with regard to the vertical reciprocal forces. The CITS opposing piston actions compensate a proportionately larger portion of their vertical reciprocating forces, by having their axes just 38 mm apart. As mentioned earlier, NTS's cannot exploit this advantage, as they need to seal the two crankcase voids from one another.

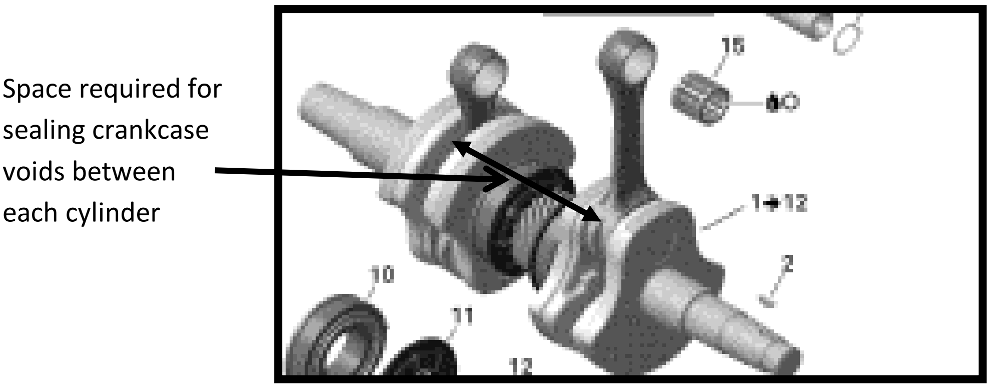


Figure 13 Typical 2 stroke twin's long crankshaft with opposing counter-balances, widely spaced.

Figure 14, is a photo of the four-stroke twin crankcase and used for our prototype, and shows the original large crankshaft counter-balance required, demanding unusually long, and thus heavier, con-rods, to keep the piston skirts

clear of its swing at bdc. The CITS smaller crankshaft counter-balance and con-rod small-ends are outlined in broken lines. It is plain to see that the CITS V-twin has made possible for the first time, the lightest and best balanced simple V-twin cylinder IC engine yet seen. This leads to significant engine weight and production cost savings when compared to a 4 cylinder of the same output, becoming available to the motor industry.

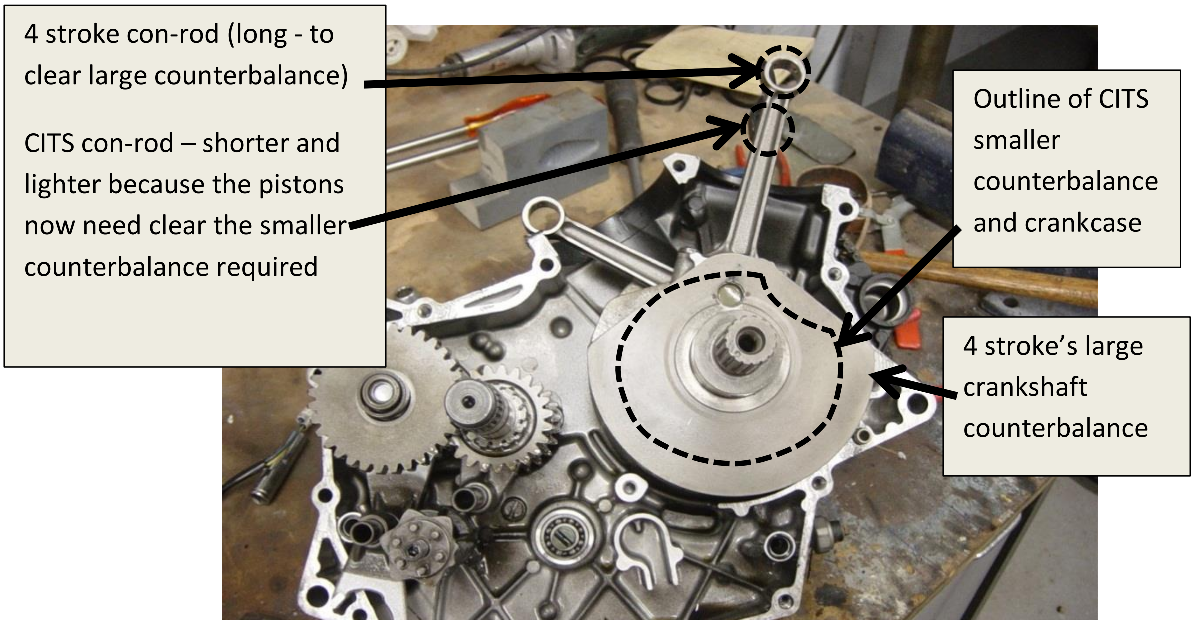


Figure 14 4 stroke vs CITS counterbalance and connecting rods comparison

13 Other Advantages

13.1 Reduced hydrocarbon emissions with the CITS piston

The rocking of the normal IC piston caused by the rotational friction of the con-rod at or near TDC and BDC is caused by the high G loadings experienced there. This causes wear patterns at the top and bottom edges of the piston's thrust faces – especially on today's short skirt 4S pistons. Piston-top guidance against the cylinder-walls creates aluminium ***smear*** across the ring grooves, seizing the rings, due to friction on the already-hot piston crown. As a solution, the piston-ring-lands in today's four-stroke engines are **undercut** to avoid all cylinder contact. This creates additional unwanted HC traps between the rings, carrying unburnt fuel, and contributing to harmful HC emissions as shown in Figure 15.

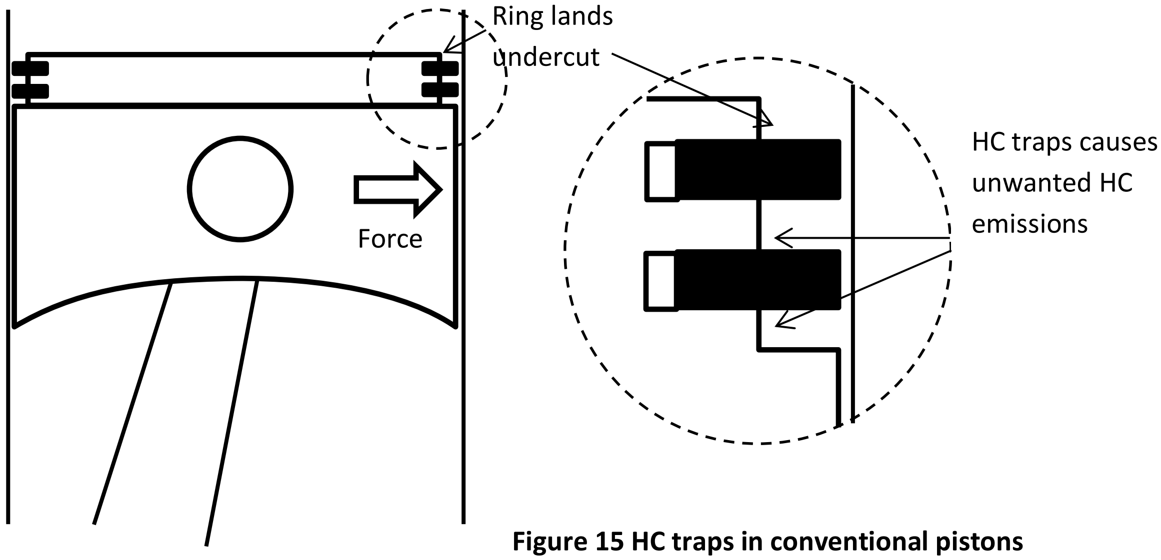


Figure 15 HC traps in conventional pistons

Current designs are minimising groove clearances even ***behind*** the rings to lessen all HC traps. In the CITS piston, as shown in Figure 16, the piston alignment control points can be approximately 300% further apart, reducing the

piston-rock angles in inverse proportion. That advantage, plus the unique **elimination of lateral loads** on the CITS piston, allows the CITS piston lands to be ***flush*** with the piston thrust faces, improving 3 factors:

1. Reduced piston heat due to elimination of side thrust.
2. Greater heat transfer to the water-cooled bores.
3. Minimisation of piston HC traps.

In addition, the CITS engine has one piston ring, or two at most, compared to 3 on most 4 strokes. See Figure 16 pg 19.

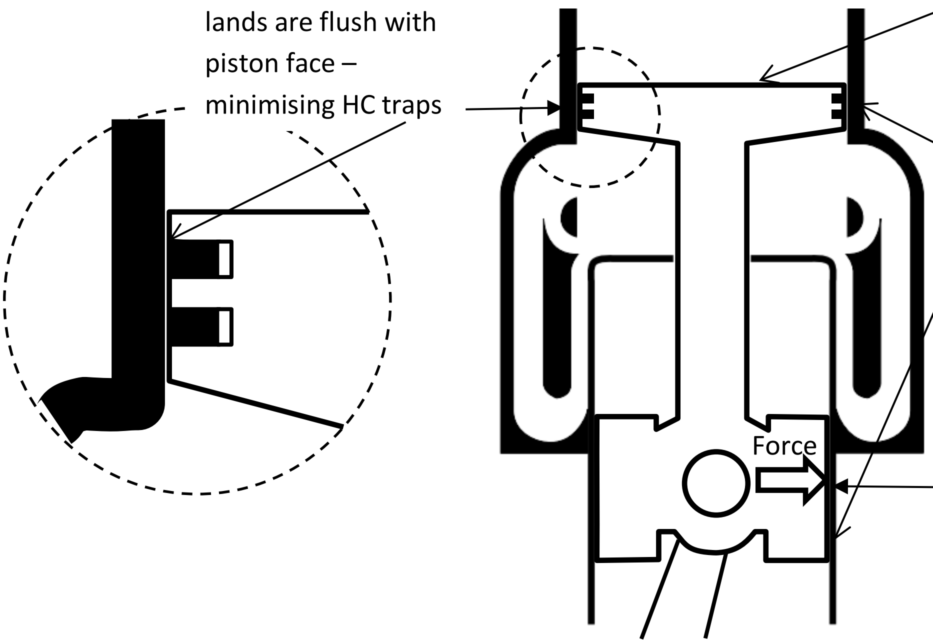


Figure 16 Reduced HC traps in the CITS piston

13.2 Piston cooling

Cooling of the piston is vital in the NTS, with only one stroke between power strokes, (compared with three in the 4S) and has been closely considered in our water-cooled street-use 6500 rpm CITS engine. On examination after the early air-cooled single cylinder CITS prototype dynamometer tests, the piston showed no signs of distress. Interestingly, NTS piston-cooling is no problem even with the extreme rpm and outputs of *Moto* GP competition. This is in part, due to something unique to the NTS piston cooling, which is the piston and ring's passage across the fresh-charge-filled windows of the 5 transfer ports which straddle the piston near BDC, as well as the fresh inducted charge cooling the piston's **underside**. This cooling effect is absent from the hottest exhaust port segment, resulting in an increased thermal gradient at this sector of the CITS piston crown. Conveniently, the unique skirt-removal from sections of the CITS piston, is not done in this vital sector, and so the full length exhaust skirt remains there as a heat-sink in the normal way, cooled by the fresh charge on each rising of the piston. At the critical piston-crown **centre**, the CITS piston-post acts as an **additional** heat-sink, being cooled in the crankcase oil-mist on its down-stroke, and by the inducted cool charge on its up-stroke. Thus the hottest areas of the CITS piston-crown is now book-ended by two

well-cooled heat-sinks. In addition, the greater proximity of the CITS ring-lands to the water cooled cylinder walls will further improve heat transfer.

13.3 Piston lubrication

Piston lubrication in the NTS is achieved, even in the demands of competition, by the crankshaft's lubricant migrating along the popular Schneurle loop-scavenge circuit. This total-loss-lubrication of around 1:50 oil/petrol ratio is required to lubricate the NTS roller bearings in the crankcase, and hence this heavy oil-load burdens the NTS combustion too, in heavy droplets. In the CITS engine, because the inducted air and injected fuel is left oil-free, some crankcase mist off the lubricated crankshaft is used instead. The piston-post is immersed in this oil mist during its descent, and a residue is atomised on its ascent, past the seal to be surface-guided on its journey through the pressure chamber and transfer port. The heavier droplets centrifuge out on these surfaces, to drain via a tiny valve on each stroke to the crankcase. The lightest vapour migrates along the same Schneurle path as the NTS, and is thus introduced both below and above the piston at high velocities, and upon the piston-rings and sides, as they pass the transfer ports that straddle them. The oil/fuel ratio needed for **this** lubrication, can match or even better the typical 1:2500 of the 4-stroke's oil/fuel consumption ratio (the major portion being the oil burnt off the 4-stroke cylinders during combustion). Because the 4 stroke has oil splash only to **below** the piston, very little is left at the upper cylinder after being scraped down by the piston, then by its oil-scraper ring, and finally by its second ring, leaving little to the top ring. This is what gets consumed on the four-stroke's bores in combustion, and these conditions make the ring's journey near tdc in the cylinder, the area of recognised **maximum cylinder wear** due to marginal lubrication, high temperatures and low ring velocity. Hence the common "wear ridge" found in worn engines at the top of the cylinder, but never the bottom. Aggravating this is the oil is sucked up to the top ring at high vacuum or throttled situations when it is **least needed**, and blown down by compression under power situations when it is **most needed**. The CITS cylinder instead gets a similar oil supply to upper and lower zones.

The NTS and CITS oil-to-cylinder distribution is therefore more equal at both top and bottom, an advantage in this region where ring-scuffing takes place, due to the triple combination of heat, pressure and the piston-ring stopping at TDC. The oil/petrol ratio of the CITS engine will be a dramatic drop from the typical 1:50 oil/petrol ratio being burnt or emitted to the exhaust in the NTS. The CITS piston and slipper, with a typical clearance to cylinder of say 0.25 mm, leaves just 0.125 mm as the amount a floating seal need accommodate the post's lateral gyrations from its centre-line, as shown in Figure 17. The oil control is achieved by controlling the density of the oil-mist within the thimble by means of an oil-shroud capping it, with a slot for the con-rod.

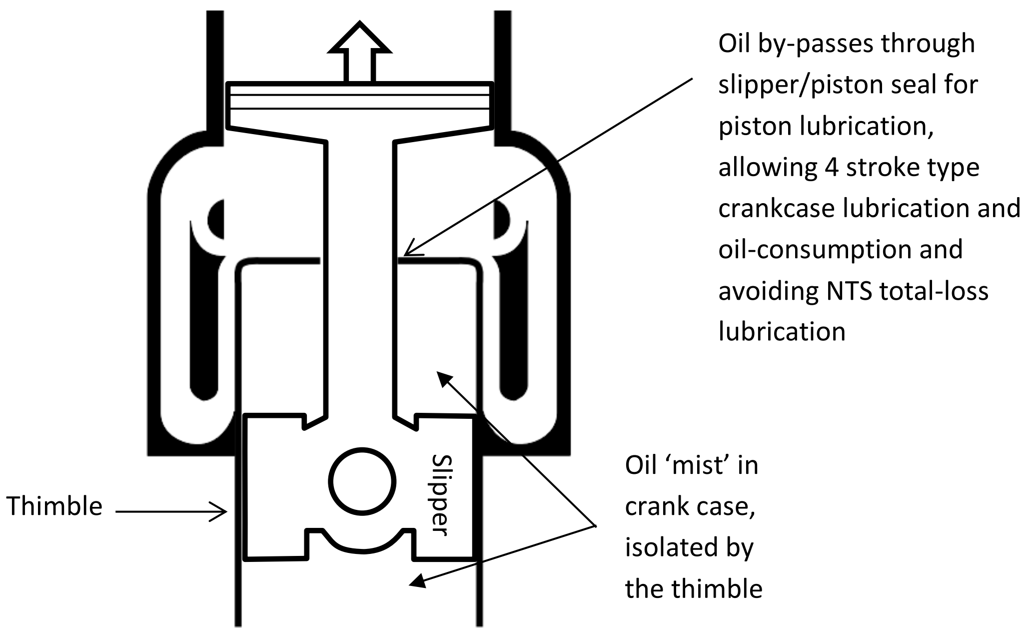


Figure 17 Piston lubrication

This task of sealing the CITS piston's hot reciprocating shaft is similar to the successful sealing of the 4 stroke's valve stem and guide. It is even less problematic, because here, the CITS piston-post is accurately guided both above and below the floating seal, unlike the four-stroke's valve stem – and the ratio of the clearance to valve-stem diameter ratio is far larger than in the CITS piston-post-to-thimble case. To allow for manufacturing concentricity tolerances, the seal recess will allow the seal-lip to flex laterally and find its own centre, ensuring adequate compliance. The seal is designed to be replaced from the top, a small task on a two-stroke, by just removing the head and the piston off its post, should the seal's life be any less than that of the rest of the engine. On the PHEV, the back-up combustion engine may run rarely, or even never – making the durability issue an interestingly new paradigm. The engine should outlast the chassis! The CITS crankcase oil may never need changing, as it receives no blow-by pollution and contaminants like the four-stroke's do, being isolated by the thimble from such contamination.

14 CAD Model

The CITs engine has been CAD 3D modelled per the cutaway shown in Figure 18.

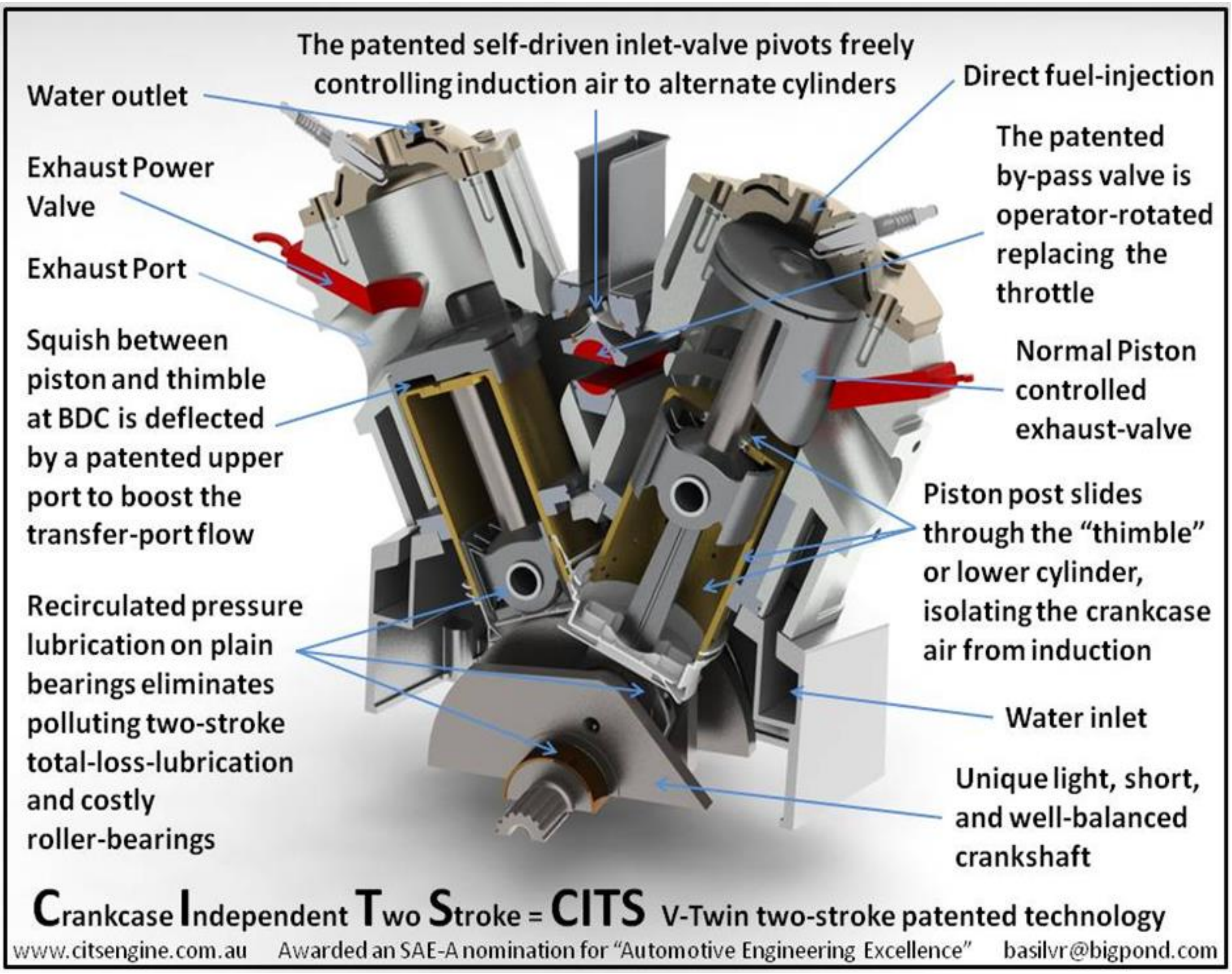


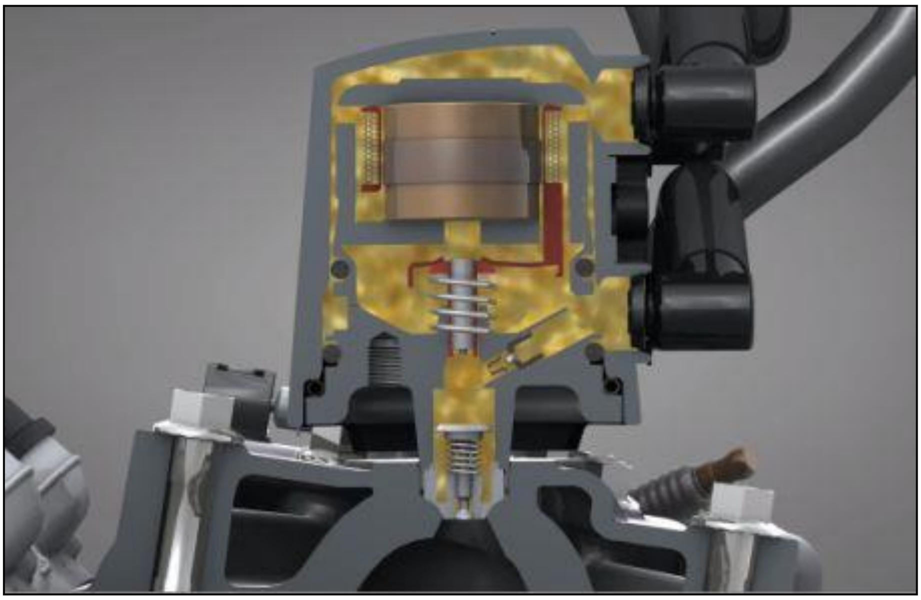
Figure 18 CITS CAD Model

15 SAE Article on ROTAX 800H Two-Stroke.

Below is an extract from the authoritative on-line SAE International on the remarkable ROTAX 800 H normal two-stroke (NTS). Note its benchmark-setting output of 115 kW/155 bhp from just 800 cc for recreational usage. This is **double** the specific output of current 2.2 litre 4 stroke engines, from less than half their size and weight. This astounding 145 kW/l comes with new levels of economy and emissions for an NTS. But it is still burdened by **TLL** (**total-loss-lubrication),** and high imbalance forces of the parallel-twin causing vibrations**.** Imagine this remarkable engine, with CITS technology, **eliminating** the total-loss lubrication, reducing the high imbalance forces, with cylinder axes over 60% closer. Then add the CITS's higher PCR at power, and lower PCR at idle, from the By-Pass valve (https://youtu.be/hLj-hk61GzA)**.** This framework promises a range of light, low cost V-twin engines from 250 to 1250 ccs, giving about 90kw/litre at modest rpm, as a range-extender hybrid for all cars, or sandwiched into up to V8 8liter engines for portable generators and pumps or sports cars, with 800kW. Clearly new benchmarks might be set, and allow the CITS two-stroke to find its place on the world's roads and in industry.

Direct injection keeps two-stroke alive for Bombardier in 2012
26-Apr-2010 17:42 GMT

Electromagnetic injectors mount vertically on the liquid-cooled 800R twin's cylinder head. In this cutaway view, note the internal coolant passages; the engine circulates fuel to help cool the injector.



The last major bastion of the two-stroke engine appears to be in snowmobiles. Thanks to liquid cooling, electronic controls, fuel injection, sophisticated combustion techniques, and variable-exhaust-port technology, the latest avalanche of two-stroke "sled" power plants aims to comply with the new U.S. EPA Phase 3 emissions regulations slated for the 2012 model year. Can the two-strokes, with their impressive specific output, high power-to-mass ratio, and package benefits, hold their own against the four-stroke assault? Bombardier Recreational Products (BRP) engineers believe they can. BRP's evidence is the recently unveiled Rotax E-TEC 800R, newly equipped with direct fuel injection (DI) and slated for 2011 Ski-Doo sleds. (BRP owns Rotax, Ski-Doo, as well as Evinrude marine engines and Sea-Doo watercraft.)

The injected 800R is the latest iteration of Rotax's Type 797 series, an 800-cm^3 liquid-cooled parallel twin rated at 155 hp. (115 kW).

The Phase 3 standard mandates a nominal 50% reduction in carbon monoxide (CO) and hydrocarbon (HC) emissions

compared with uncontrolled levels (150 g/kW/h for HC and 400 g/kW/h for CO). The straight HC limit is 75 g/kW/h, and the corporate average CO limit is 275 g/kW/h.

For two-stroke engineers, the main HC emissions challenge is achieving a complete burn in the combustion chamber. With its DI system, Rotax's development team employs the company's voice-coil electromagnetic injectors to further compress the fuel from the relatively low initial pressure provided by the fuel pump and simultaneously inject it into the 800R's cylinders at 500 psi (34 bar).At this pressure the fuel stream vaporizes almost instantly and is then ignited by the spark plug. This creates a more complete burn as well as better throttle response when compared with the previous carburetted two-stroke, BRP engineers claim. As part of their cleaner emissions profile, the DI E-TEC engines also have greatly reduced exhaust odour during start-up.

The DI system is used in conjunction with BRP's reed-valve induction, 3-D RAVE (Rotax Adjustable Variable Exhaust) electromechanical exhaust valve, and a powerful ECU that processes inputs from a variety of sensors—crank angle, throttle position, knock, coolant temperature, and ambient air pressure and temperature. The open-loop fuel system also cools the injectors as well as the ECU. The 3-D name refers to three-dimensional mapping used to determine exhaust valve operation, as well as three exhaust port openings per cylinder. The new injected 800R achieves a claimed 19 mpg (12.3 l/100 km) in Ski-Doo sleds—up to 37% better fuel efficiency than competitive units, BRP claims.)Other benefits of DI include easier starting, improved idle quality, and greater oil efficiency—264 mi/qt (450 km/L), a 15% improvement over the 2010 carburetted 800R, according to the company. The addition of DI to its 800-cm^3 engines (the 600-cm^3 units are similarly equipped) proves the two-stroke is alive and, for the time being, still very well indeed. *Lindsay Brooke*

Successful Early CITS Single Cylinder Prototype

Parts of the early prototype engine are shown in Figure 19. Note that no special machinery and methods are needed in the manufacture of the CITS engines.

Figure 19 Early CITS (single cylinder) prototype

Data from early tests on our single-cylinder CITS prototype is shown in Figure 20, independently scrutineered and supervised. Being air-cooled made the thermal loads demanding, and on stripping the engine, the piston was found to

have no signs of heat stress. The engine was run on pure petrol, with oil in the crankcase, at a level to be licked by the con-rod for lubrication of the isolated but regular two-stroke crankcase contents.

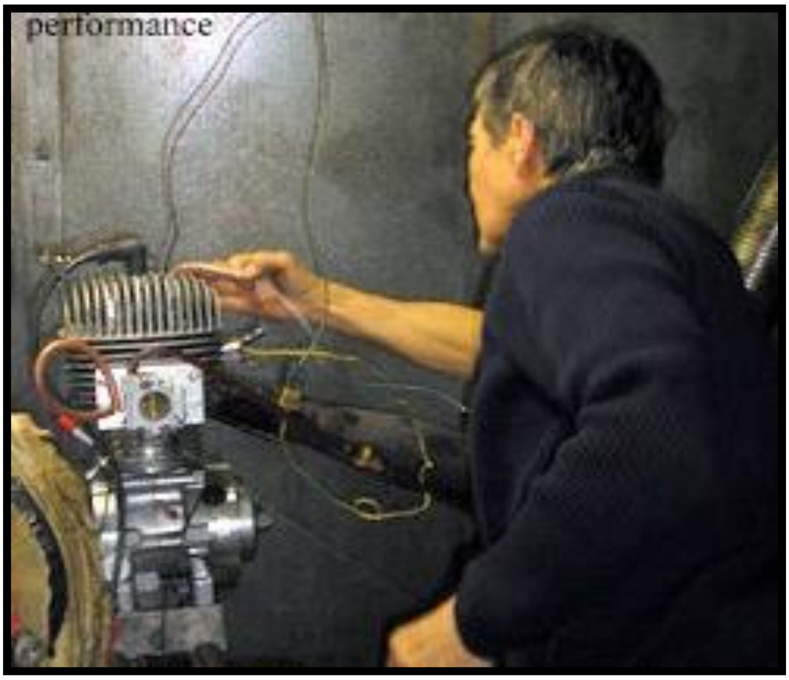


Figure 20 Tests on the early CITS (single cylinder) prototype

A CITS single cylinder prototype based on a Yamaha 100 cc kart engine was tested, first as a normal two-stroke, and after as a CITS 2S, on July 3, 9 and 20, 2007 on the Stones Karts' dynamometer (A W. Sydney Yamaha agent). The results are shown in Figure 21. The petrol used was oil-free.

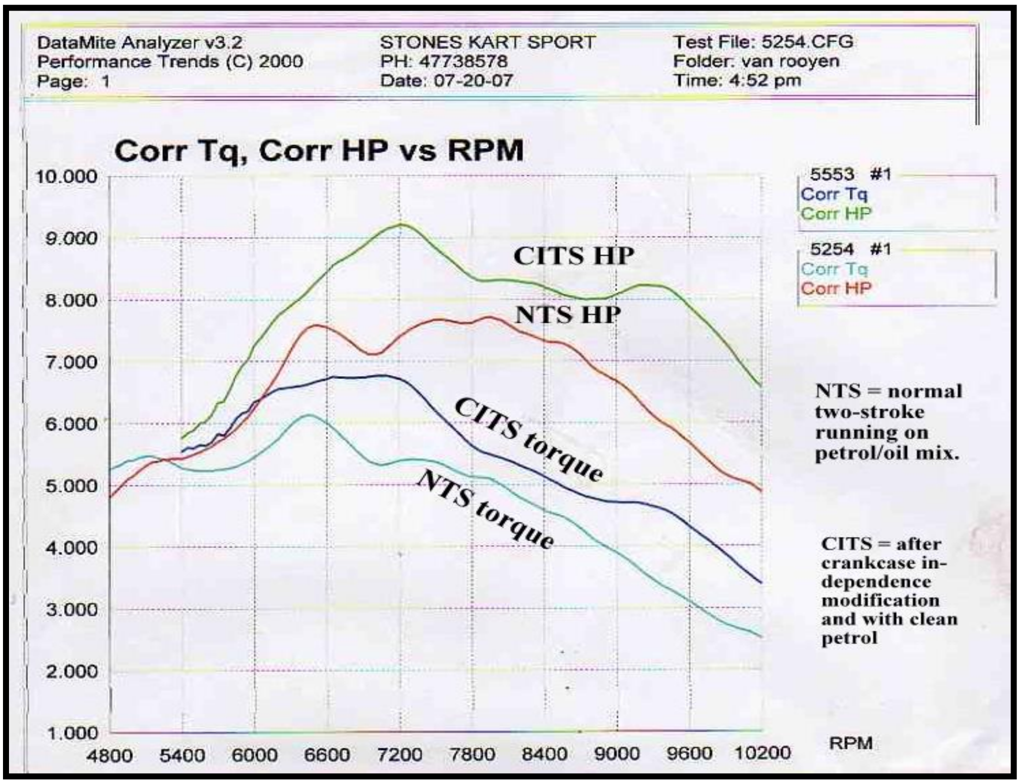


Figure 21 Data from independent tests on the early CITS (single cylinder) prototype

The engine was supplied new by Stones Karts and converted to CITS by Ralua Engineering, and all performance related items normally scrutineered for racing, were retained to get valid data comparison. This included the carburettor, all the port windows, inlet and exhaust ports, the exhaust system, the restrictor plate, the ignition,

Spark-plug, cylinder head, piston height and even the original piston-ring. All parts were scrutinised by Mr Stones who acts as a scrutineer for kart racing. The purpose was to check that:

1. The piston head would show no signs of overheating or galling, and that the piston post would be robust for short term testing to 10,000 +rpm and that the air resistance from the lower slipper, and the post's reduction of the piston area for induction, would not unduly reduce the power output.

2. There would be adequate output, despite the poor design of the CITS transfer ports due to retro-engineering compromises.

3. The upper cylinder would be adequately lubricated by the by-pass of crankcase oil mist between the post and the divider plate when running on straight petrol.

Lubrication of the lower bearings was achieved by filling oil in the crankcase to a level just touching the crankshaft for splash. The test was carried out over 3 days, by the proprietor Mr Stones, whose phone number is on the test sheet. Neither the temperature, barometric pressure, nor humidity, was accounted for due to the nature of the test, on 40 various runs which were all run during fine winter weather. Due to the design restrictions caused by modifying an existing engine to CITS, the increased torque was an unexpected bonus. Especially satisfying was the excellent appearance of all parts on stripping. This indicated that the way forward was clear, for further CITS development in long term reliability and efficiency, with a CITS engine running on pure petrol. Also present was Mr Don Riddell, a CITS shareholder, Mr John Black, B.Sc. Mech. Eng., also a shareholder, and Mr Basil van Rooyen, the inventor and designer.

Subsequently a CITS V-twin was prototyped shown in Figure 22, with the tiny patented pivot and by-pass valves **replacing** the large reed-valve-throttle assembly, typically as wide as the cylinder-block. At the prototype's first start-up, it ran as smoothly as predicted, surprising even the experienced Motec injection/ignition technicians.

Figure 22 V Twin prototype with pivot valve

16 An Independent Report on CITS technology

This report on pages 26 and 27 was provided by an internationally-recognised authority, Emeritus Professor Brian Milton. Due to the length of this report, relevant extracts are provided. The complete version is available on request. Further expert comments follow on page 27.

Abridged CV of Emeritus Professor B Milton

Professor Milton was Head of the School of Mechanical and Manufacturing Engineering from 1989 until his retirement at the end of 1998. From 1965 to 1966, he obtained a Master's Degree (MSc in Thermodynamics and Gas Dynamics) from Birmingham University (UK) followed by a PhD at the University of New South Wales, Australia from 1967 to 1970. After his retirement, he was awarded the title of Emeritus Professor by the University and has continued with an active participation with research and post-graduate research students as well as a strong interaction with undergraduates in his specialist course of Internal Combustion engines.

During his academic career, he spent extensive research periods at NASA and the University of Nottingham, (1977-78), Massachusetts Institute of Technology, MIT (Sloane Automotive Laboratories) (1982), University of Bath (Wolfson diesel engine laboratory) UK (1986) and the Institute of Fluid Science, Tohoku University, Japan (1985, 1991, 1994). He has also developed international collaboration with Korea and China.

He published around 200 articles that include books, edited books, journals and conference papers. These are in his two research areas of high speed gas dynamics, (particularly shock wave fundamentals and applications) and in Internal Combustion engines, including alternative fuel operation and usage, fuel/air preparation and mixing, fuel injection and sprays. He was in charge of the Internal Combustion Engines Laboratory in the School from 1974 to 2002. He has written over one hundred consulting reports for Australian Industry.

Extracts from Emeritus Professor B. Milton's appraisal Report dated 22/8/2011

My opinion is that there are genuine possibilities for these improvements to take place. It therefore represents a significant advance in the development of a two-stroke engine which could well be competitive in the automotive market currently dominated by four-stroke engines.

…the engine appears to be workable, cheap to manufacture and has the possibility of equalling or perhaps exceeding current best NTS (normal two stroke) power outputs. It is very likely that its CO and HC emissions will be lower than these and quite probable that its specific fuel consumption will be an improvement hence reducing CO_2. Unlike systems where the lubricating oil is pre-mixed with gasoline, it makes the best use of modern fuel injection methods. While its cylinder configuration is not limited, it is currently proposed as a V-twin. An initial evaluation of the engine balance indicates that this will be better than a conventional 4-stroke V-twin with a single throw or two-throw crankshaft or that of a parallel two-stroke twin.

…the engine height will still be lower than the equivalent 4-stroke and it will be lighter in weight.

The CITS design has considerable potential. The fact that the piston is held rigidly in line with the cylinder centreline is in fact likely to be advantageous in regard to wear. Overall, the concept is one of the most promising that I have seen for a low cost, fuel efficient, lightweight and compact engine of high power output per unit weight.

It is possible that the CITS engine, because it can be better tuned for its inlet parameters, can further reduce or even eliminate any margin for an under-piston compression type design.

From a mechanical point of view, it frees up the cylinders so that each acts independently in a much simpler manner than isolating sections of the crankcase in multi-cylinder NTS engine arrangements. So even on that score alone, it makes a noticeable improvement to the NTS engine.

Eliminating the lubricating oil in the fuel will also mean that the combustion is faster, more efficient and clean. Its innovative scavenging system gives it considerable potential.

Major tooling and manufacturing changes are not needed for the CITS engine which could aid rapid introduction.

Being small and with its fuel uncontaminated by lubricating oil, it should be easily started hence fitting well into the micro-hybrid systems with stop-start facility.

The overall feeling is that an alternative to the IC engine as the major automobile power source is at the shortest, several decades away.

…the turbocharged diesel will be noticeably more expensive to manufacture than the CITS 2-stroke considered here and will be heavier and larger in total package. The CITS concept therefore has considerable potential. In addition, doubts exist about the overall ability of Electric Vehicles to reduce CO_2 emissions from source unless a very substantial increase in electrical power generation from renewable sources to replace coal occurs.

The following comments on the CITS engine technology are from other noted experts in the field of motor engineering:

M/S Dr. Stephen Samuel, of Racing Engine Design, Professor John Durodola, of Advanced Strength of Components and Federico Bengolea, Master of Science, at Oxford Brookes University, Oxford, agreed in the following points:
The concept of the engine is very good. Takes the best out of the 2 stroke and 4 stroke engines and combines it achieving: Better indicated efficiency, and reducing emissions to 4 stroke level, at least. Definitely viable for production.

For CITS engine technology, the inventor was awarded a nomination by the SAE-A (Society of Automotive Engineers)
For Excellence in Automotive Engineering. (See page1 of Engine Overview in our website)

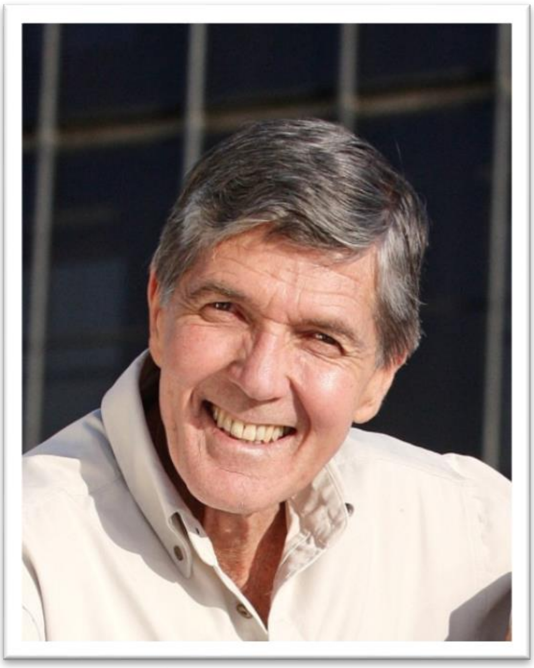
Mr. Izmir Yamin – aero-space engineer https://forum.lowyat.net/topic/3550031/all
I am immediately impressed by your diagrams of the CITS engine. I must say it is genius.

17 About the Inventor

Basil van Rooyen has enjoyed a successful business career, as CEO of 3 manufacturing businesses, all leaders in their fields, as well as being an innovative motor engineer, and a champion racing driver, with a string of victories in production, sports and F1 cars. His career history can be seen at: www.basilvanrooyen.com

Since "retiring" in 2008, Basil has had several patents registered in his name, the most recent commercialised one being the Twister, a pool cleaner device which solves the world-wide problem of pool cleaners getting stuck in corners. Google ***pool Twister*** for details if of interest.

He has spent 5 years developing this CITS technology, and has shown the persistence needed to bring it to this advanced stage, and hopefully for it to reach its destiny.



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For his CITS engine technology, Basil van Rooyen was awarded a nomination in

SAE-A "Automotive Engineering Excellence Awards 2012" in Melbourne, in September 2012.

The citation read:

"In recognition of excellence embodied in the nomination of 'CITS engine technology' and its benefit to the Australian Automotive Industry and Community"