Notes on the Toyota AW11 4AGZE Supercharger System

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Overview

The Toyota 4-AGZE motor was used in the 86-89 MR2 Supercharged edition MR2s. The motor is a modified 4-AGE unit coupled to an electronically engaged roots type supercharger (manufacturer currently unverified) and a Nippon Denso air-to-air intercooler. Static compression ratio of the motor was dropped from 9.4:1 to 8.0:1. The camshafts are identical to a normally aspirated car, although their timing may be different. The motor is fitted with a different type of injector with a higher flow capacity. Boost level is set at 8 PSI and achieved at 4000 RPM and higher, however the supercharger creates usable boost from idle through redline.

The supercharger is driven by a serpentine belt off of the crankshaft and shares it's drive belt with the water pump. An electromagnetic clutch is installed on the supercharger, allowing it to freewheel when it is not needed. The clutch is controled by the engine's electronic control unit (ECU). A combination blow-off/bypass valve is provided to route air around the supercharger when the clutch is disengaged or when boost exceeds 8 PSI (nominal). The valve is operated by manifold vacuum/pressure. The ECU has the ability to force the bypass closed via an electronic vacuum cut off solenoid valve.

The rear engine cover was modified to increase the height of the vents to clear the intercooler. The passenger side engine cover vent was closed off and the driver side vent had moulding added on the inside to seal against the top of the intercooler. The engine cover is also made from fiberglass rather than stamped steel.

An oil-to-water cooler was added, the transmission and drive shafts were upgraded and a 10mm larger clutch was was added along with a new flywheel. A green light emitting diode indicator located on the tachometer and labled "Supercharger" is activated by the ECU whenever intake manifold pressure is positive. An engine knock sensor and a fuel octane selection switch were also added. The supercharger and transmission changes add almost 200 lbs. to the car.

T-tops were installed on all Supercharged models.

Components

Supercharger

The supercharger is a roots type unit, manufacturer is unknown at this time. The lower vane is driven by the pully and drives the upper vane via gears located in the rear of the housing. The gears are run in Toyota supercharger oil, Toyota part number 08885-80108. The lubricant costs about $50 for 50ml. Total gearhousing capacity is 130ml.

Two special tools are required for disassmbly of the supercharger; SST 09504-00011 for keeping the pully from rotating while you undo the nut that holds the clutch hub to the supercharger. If you have an impact wrench you might be able to get by without this for removal. However you will still need something to hold the pully when you tighten the nut down upon re-assembly. SST 09814-22010 for

removing the ring nut that holds the clutch pully on. You can't get by without this short of having a set of ring nut sockets or custom building the equivalent tool.

Vent holes are placed at three points in the housing. One in the rear gear housing and one to each of the shaft ends of the vanes on the front of the supercharger. The vents are all connected together via external metals tubes and hosing. An air valve is connected to all the vents which can purge them to the intake system after the airflow meter but before the throttle body.

The supercharger adds heat to the intake charge both by conduction of housing heat since the supercharger is bolted onto the engine and also by pressurizing the intake charge. With the bypass valve open and the supercharger disengaged the intake system raises the intake charge temperature by about 30 degrees F once everything is up to operating temperature. Running under full boost with an outside air temperature of 50 degrees F the air temperature of the SC outlet can get as high as 270 degrees.

Supercharger clutch

The supercharger clutch works in the same way as an air conditioning compressor clutch. The pully itself spins freely on the supercharger input shaft. A coil of wire sits behind the pully and a metal disc sits in front. The front disc is connected to the actual input shaft of the supercharger. When the coil is engergized, the disc is drawn against the rotating pully and they then rotate together as a unit untill the coil is de-energized.

The ECU engages the supercharger based on intake manifold vacuum. When the vacuum drops below 8" the supercharger clutch is engaged. The clutch stays on untill the intake manifold vacuum has risen to over 10" for a period of 5 seconds. This time delay was added to avoid cycling of the clutch during shifts and momentary throttle transitions.

The clutch is operated by the ECU via a relay that lives in the rear trunk right next to the ECU unit itself. Both are located in the center of the engine/trunk behind the pressboard trunk liner. The relay operates the clutch by grounding one side of the coil. The other side of the coil is connected to +12 volts when the ignition is in the ON position.

An intersting note is that the manifold vacuum will be low enough during highway driving that the SC clutch will stay engaged all the time. This typically occurs at speeds over 65 MPH. My cars milage ran around 26 miles per gallon under these conditions.

Air Bypass Valve

The air bypass valve (ABV) serves two functions. The first is to provide a route for air to bypass the supercharger when it is not spinning. The second is to act as a blow-off valve when boost exceeds aproximatly 8 PSI. The blow off point varies significantly between cars from 8 to 10 PSI.

The valve is attached to the rear of the supercharger and is closed when the car is not running. It is in effect, a spring loaded plunger that blocks a port that runs from the supercharger inlet to the outlet. When the intake manifold pressure on the plunger exceeds the spring pressure, the valve starts to open, allowing the outlet side to discharge some of it's air back into the inlet. This sets the maximum boost pressure.

The bypass function is achived by adding a vacuum operated diaphram on the back side of the valve, which pulls the valve open. As soon as the car turns over, intake manifold vacuum is created, which is routed to the diaphram and opens the bypass port. As the throttle is opened, vacuum in the intake manifold drops and the valve starts to close. The valve starts closing around 4-5" of intake manifold vacuum and is fully closed by 1-2". Since the computer has activated the SC clutch when intake vacuum

dropped to 8", the supercharger starts spinning while the bypass valve is still open. The valve starts closing with the supercharger already spinning thus creating a gradual smooth transition from an open to closed intake system.

The computer also controls a solenoid valve that vents the vacuum diaphram on the air bypass valve to outside air. By doing this, the computer can cause the ABV to close irregardless of intake manifold vacuum. This valve opens as soon as there is positive pressure in the intake, thus keeping the diaphram from working in reverse and pushing the ABV valve closed more tightly as intake pressure increases. The computer also holds the ABV closed this way when there is sudden vacuum in the intake, such as when you release the throttle during a shift. This way the intake system stays sealed to the supercharger while you shift and the system does not have to re-seal when you step on the gas again. After several seconds of closed throttle (constant vacuum in the intake), the computer releases the valve and disengages the supercharger.

Interestingly, connecting the diaphram directly to the intake system, thus causing the valve to cycle open during shifts does not produce any noticable change in throttle response.

Intercooler

The intercooler is a Nippon Denso unit (part # 127100-0153) with 19 cores. Surface area is 200mm X 290mm with a depth of 65mm. The inlet and outlet tubes run the length of the intercooler and are 50mm in diameter.

When the car is in motion, air is drawn in via the side vent located on the passengers side of the car and flows over the engine and out of the compartment via the intercooler. The side vent has positive pressure and the area over the engine cover has negative pressure.

At 65 MPH air entering the vent increases in temperature by about 10 degrees F before reaching the intercooler. Suprisingly, the temperature increase stays below 15 degrees all the way down to 20 MPH or so. Increasing speed over 65 does not make a significant change.

At idle the underhood temperature rises to about 120 at which point the fan installed in the side vent activates, bringing the temperature back down to about 100 degrees before shutting down. Note that the temperatures above were measured directly below the intercooler. Under hood temperatures vary considerably by location, for example the the fan sensor, which is located nearthe exhaust manifold activates at ~160 degrees F and disengages at ~130 degrees.

Intake charge temperature drops between 100 and 50 degrees depending on conditions. When the intercooler is cold, full throttle opening will yield a 100 degree temperature drop which then falls back to a low of 50 degrees as the intercooler itself heats up. 10 seconds after 1/8 throttle to full throttle opening the intercooler temperature drop is down to 75 degrees and within 30 seconds falls to 60 degrees, falling at a slower rate after that. Unfortunatly I did not have a data logger available at the time so I cannot provide any chart data.

Actual outlet temperatures were as follows with an outside air temperature of 59 degrees F.

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Partial throttle cruise at 70MPH (SC engaged, 8" vacuum)        100 F
Partial throttle cruise at 70MPH after full boost run           130 F
Idle, engine compartment fan on.                                 100 F
Maximum observed outlet temperature (long uphill run, 10 PSI)   200 F
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Air Vent Control Valve

The valve connects the supercharger gear case and end seals to the intake system before the throttle body. The valve is operated by the ECU. With the valve closed, pressure inside the vent system runs about 1/2 of the manifold pressure (or vacuum as the case may be).

I suspect the reason for this is to minimize the pressure differential between the vane end seals and the outside air. The ECU opens the vent line when manifold intake vacuum is betwen 0 and 3".

Knock sensor

The knock sensor is attached to the engine block and sends the ECU an electrical signal that corresponds to engine vibration. The ECU filters the signal for frequencies of interest during a time window that is syncronized with crankshaft rotation to look for a characteristic signal that is produced during knocking.

If knocking is detected the ignition timing is backed off and then slowly returned to normal unless knocking is detected, in which case the cycle starts over. The detection time for knocking is in the 1-2 second range. I don't have values for the amount of timing back-off or the return-to-normal speed. No attempt is made to drop the boost level when knocking is detected.

Gas selection switch

A switch is provided on the dashboard to select what type of gasoline is in use (high or low octane). Function is currently unknown, although changes in ignition timing would be expected.

Supercharger oil replacements

The cost of Toyota SC lubricant is quite high. Other types of SC lubricants may work satisfactorily. Other places to try for lubricant are Ford (a roots type supercharger was used on the Thunderbird), GM (the Bonneville SC uses a roots supercharger) and any of the aftermarket roots supercharger manufacturers such as BI, Magnuson or Weiand. I expect any decent hypoid gear oil will work. I plan on using 90 weight synthetic gear oil the next time I am in the supercharger. After talking with several people who run roots type superchargers on race cars and change their gear oil frequently I could not find any reason why the Toyota unit would need something special. Maybe the $50 price tag is for the special syringe packaging and low volumes they sell. Or maybe they used whale oil or something...

Other sources for supercharger lubricants:

Weiand (213-225-4138)

Magnuson Products (805-642-8833)
3172 Bunsen Ave., Unit-K, Ventura, CA 93003.
146ml of NYE605 for $13 US.

Ford Motor Co.

General Motors Corp.

Numbers

Various raw data collected.

BHP: 145 at 6400 RPM
Tourqe: 140 ft/lbs at 4000 RPM
Source: Toyota

Curb Weight: 2605 lbs.
Weight Distribution: 44.5% Front / 55.5% Rear
Fuel Capacity: 10.8 US gallons
0-60 MPH Time: 6.5-7.0 seconds
Lateral Acceleration: .78-.80G
Source: Various car magazine test results.

Crank pulley/harmonic balancer diameters: 130mm alternator, 145mm supercharger.
Rim sizes: 14 X 6.0 inches (stock)
Alternate sizes: 15 X 7.0
Rim Offset: 33mm
Tire Sizes: 185/60/HR14 (stock)
Alternate sizes: 195/55/14, 205/60/14 (rear only), 205/50/14, 195/50/15
Tire circumference for best speedometer accuracy: 71" or 800mm (195/50/15)
Top Speed: 129 MPH headlights up, 132 MPH headlights down.
Boost:
3 PSI at 1000 RPM in 5th gear
6 PSI at 2000 RPM
7 PSI at 3000 RPM
8 PSI at 4000 RPM
8 PSI at 5000 RPM
8.25 PSI at 6000 RPM
RPM to speed ratio (ideal): 129.6 RPM = 1 MPH in 2nd gear.
HP measurements, 2nd gear, stock car, OAT: 60 degrees F

KRPM	MPH	Run 1	Run 2	
2-3	14-22	0.99	0.98	seconds
3-4	22-30	0.99	0.97	
4-5	30-38	0.90	1.00	
5-6	38-46	1.07	1.02	
6-7	46-54	1.17	1.17	

Calculated horsepower

RPM	HP
2500	52
3500	75
4500	101
5500	114
6500	121

Source: Measured values.

Modifications

Jumper air bypass valve diaphram to the intake manifold

This modification prevents the air bypass valve from acting like a blow off valve and disables the computers control over the ABV. Recomended for running higher than stock boost levels. A simple modification that involves running the vacuum hose from the ABV diaphram directly to the intake manifold and putting a cap on the line that ran from the VSV to the ABV. Only a T and vacuum cap are required.

HKS overdrive pully

Replacement crankshaft pulley/harmonic balancer. Provides a higher drive ratio to the supercharger and water pump. Pully diameter is 10mm larger for the supercharger belt. Supercharger makes 2 PSI more boost with no other modifications except jumpering of the air bypass valve as noted above.

Air filter

I have run my SC car with no filter element present and there was no change in boost level or measured HP. Clearly the filter is not the major restriction in a stock set up. Have not tested the HKS Powerflow unit.

Intercooler fan

Results from testing show very marginal improvements by adding a radiator type fan to the intercooler. The fan simply cannot generate enough pressure compared to the aerodynamics of the car to make a significant change in the flow through the intercooler. Intake charge temperature ran about 10 degrees lower with the fan operational. Usefull for pre-cooling the intercooler when stopped, but that's about it.

If you install one, the fan should be set up to blow out through the top of the inercooler towards the rear deck lid. This is the natural airflow when the car is moving. Running in reverse caused higher intake charge temperatures as the fan slowed down the normal airflow over the intercooler. It has been suggested that a squirrel cage type blower can provide more pressure. Some bench tests with this fan type didn't look very promising either. An air scoop on the drivers side of the car would probably work best short of relocating the intercooler.

Intercooler replacement

No tests or data available.

Problems

Belt slip

Belt slippage is a known problem with the supercharger belt. Getting the tension set right by feel is very difficult as the belt runs are short, thus making the belt appear very tight when it isn't. A tensioning gauge is highly recommended.

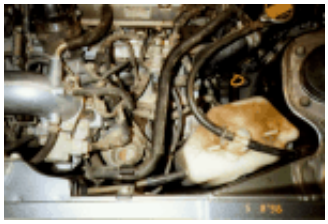
Belt slip manifests itself by a squealing or an air leaking type of sound over a particular RPM. The noise can be intermittent. A noticable drop in boost (around 2-3 PSI) is usually observed during the slip.

Prices for used and perfomance parts as of 10/3/96

All prices are in US dollars.

HKS crank pulley: $315
HKS power flow filter:
Used ECU:
Used MAF:
Used supercharger: $400-1200
Used head:
Used motor: $950
Rebuildable motor core:

Pictures



Looking at the supercharger from the top. Only the Air Bypass Valve (red and white sticker) is visible.

The radiator overflow tank has been removed. The Air Vent Control valve is the brown one on top of the supercharger with three hoses attached to it. The ABV diaphram control valve is the blue valve near the bottom with a hose running to the AVB. The brown valve in the very bottom vents the fuel pressure regulator's compensation port to the atmosphere.

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