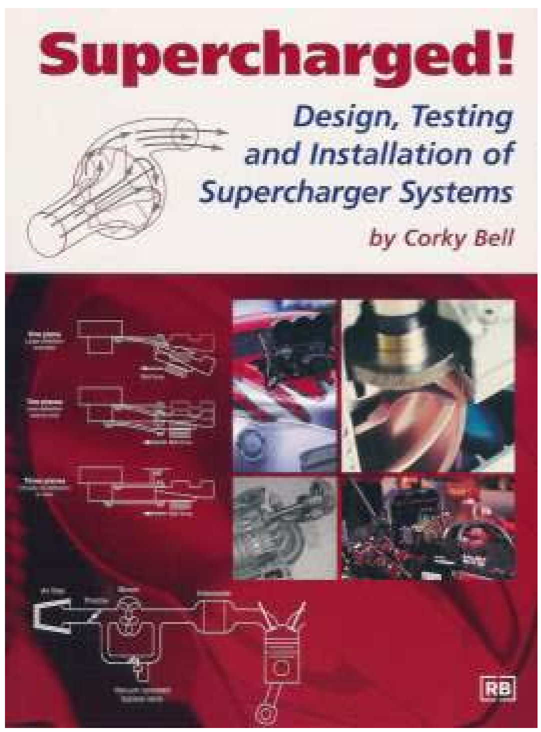
Audi A8 Supercharger Calculations for the ABZ Engine

The following pages are part of a mad scientist idea I had to supercharge my 97 Audi A8 with the 32 valve ABZ engine. I never executed it, I figure it would be about $6,000.00 to do it myself.

I had spec'd out the Rotrex blower. I was going to increase the injector size and create a pressure ratio of 1.4-1.5 to achieve peak HP numbers of 425 to 450 HP.

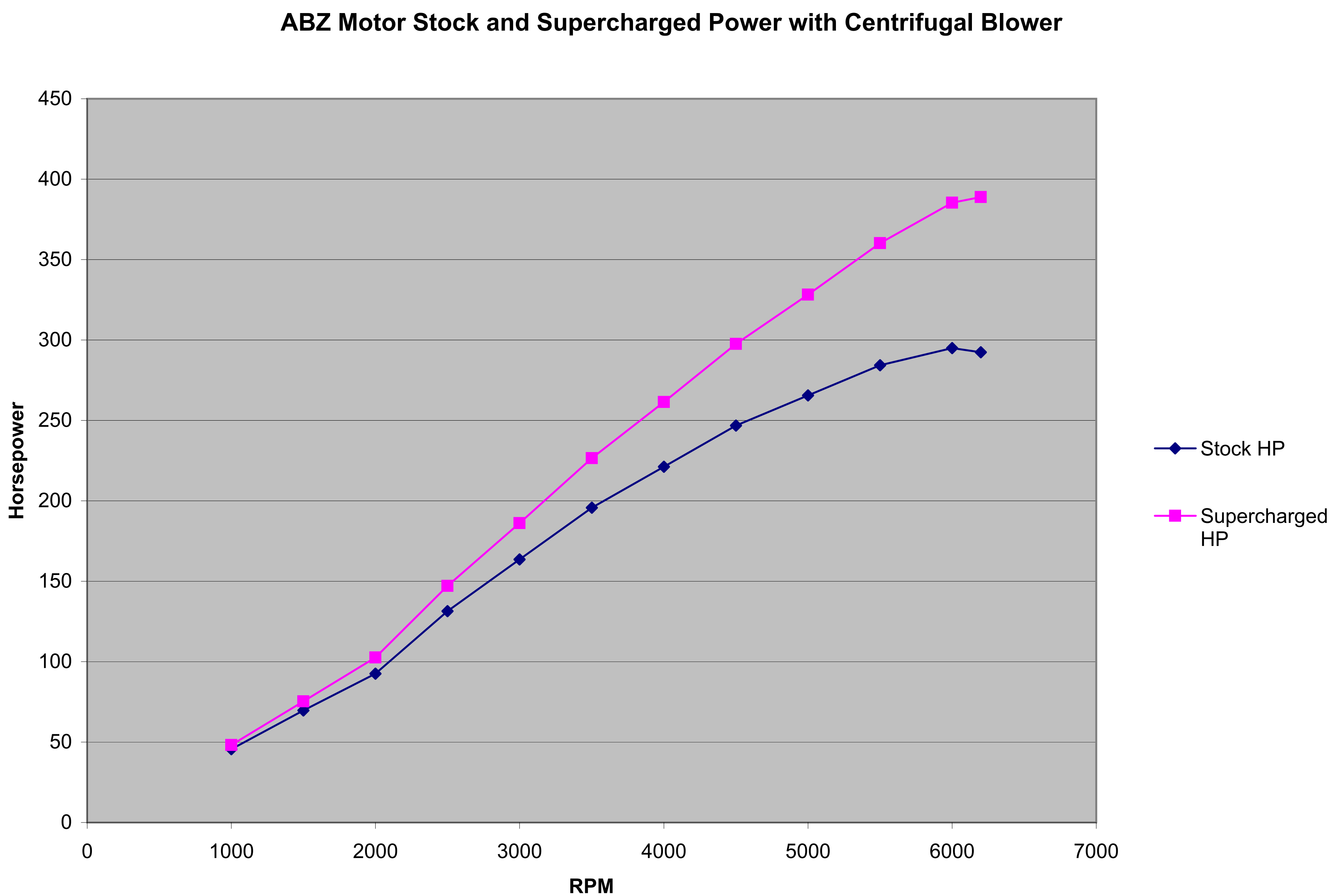
I was not going to change the engine management system; it is very difficult to do with the Bosch systems. Considering it is a centrifugal blower, a rising rate fuel pressure regulator would be used. It would be tuned on a chassis dynamometer using a wide band O2 sensor.

Feel free to use this information for your own supercharger project but please give me credit where credit is due. The calculations were derived from Corky Bell's book Supercharged! It is an excellent engineering guide.



Sincerely,

paul@audipages.com



Paul Waterloo 2005 www.audipages.com

ENGINE SPECIFICATIONS 32V ABZ

	METRIC	STANDARD
DISPLACEMENT TOTAL	4172 cm^3	254.5 in^2
CYLINDER	521.5 cm^3	31.8 in^2
BORE	84.5 MM	
STROKE	93 MM	
REDLINE	6200 RPM	
COMPRESSION RATIO	10.8 : 1	
STOCK HP	300 @ 6000 RPM	
STOCK TORQUE	400 NM @ 3300 RPM	
TEST FUEL INJECTOR (1) MIN FLOW RATE	105-115 ML / 30 SECS	3.5 - 3.8 OZ / 30 SECONDS
FUEL PUMP TEST PRESS w/ VACUUM LINE REMOVED (SHUT OFF)	4.2 BAR	61 PSI
FUEL PUMP FLOW TEST	12 VDC 460 cc/15 SEC	
	13 VDC 540 cc/15 SEC	

STOCK INJECTORS

105-115 ML / 30 SECS (3.5-3.8 OZ)

$$\frac{110\ CC}{30\ SEC}\left|\frac{60\ SEC}{MIN}\right. \qquad 220\ CC/MIN$$

$$220\ CC/MIN = \left(\frac{POUNDS}{HR}\right)\ 10.5$$

$$= 20.96\ lbs/HR$$ STOCK FLOW

$$\text{INJECTOR RATING IN POUNDS/HR} = \frac{\text{MAX BHP} \times 0.55}{\text{\# OF INJECTORS}}$$

$$= \frac{(425)(0.55)}{8}$$

$$= 29\ \frac{POUNDS}{HR}$$

@ 300HP $= 20.6\ \frac{POUNDS}{HR}$

STOCK INJECTORS

105-115 ML / 30 SECS (3.5-3.8 OZ)

$$\frac{110\ CC}{30\ SEC}\left|\frac{60\ SEC}{MIN}\right. \qquad 220\ CC/MIN$$

$$220\ CC/MIN = \left(\frac{POUNDS}{HR}\right)\ 10.5$$

$$= 20.96\ lbs/HR$$ STOCK FLOW

$$\text{INJECTOR RATING IN POUNDS/HR} = \frac{\text{MAX BHP} \times 0.55}{\text{\# OF INJECTORS}}$$

$$= \frac{(425)\ (0.55)}{8}$$

$$= 29\ \frac{POUNDS}{HR}$$

@ 300HP $= 20.6\ \frac{POUNDS}{HR}$

FUEL

BENTLY TEST DATA

12 VDC 460 cc / 15 SEC

13 VDC 540 cc / 15 SEC

1 CC = 1 ML

$$\frac{500 \text{ CC}}{15 \text{ SEC}} \left| \frac{60 \text{ SEC}}{1 \text{ MIN}} \right| \frac{60 \text{ MIN}}{\text{HR}} \left| \frac{\text{LITER}}{1000 \text{ CC}} \right| \frac{\text{GALLON}}{3.785 \text{ LITER}}$$

$$= 31.7 \ \frac{\text{GAL}}{\text{HR}}$$

THIS IS MIN REQUIREMENT FROM BENTLY

INTERCOOLER

FLOWRATE = 670 CFM

INTERNAL FLOW AREA $\cong$ 35 IN^2

$$\text{AREA OF CHARGE AIR FACE} = \frac{\text{INTERNAL FLOW AREA}}{0.45}$$

$$= \frac{35\,\text{IN}^2}{0.45}$$

$$= 78\,\text{IN}^2$$

BLOWER CFM @ 450 HP

DESIRED AIRFLOW RATE $= 424.6\,(1.587)$

$= 674$ CFM

$= 48.1$ lb/MIN

$= 0.365$ KG/SEC

@ 4125 RPM

$= 282.5\,(1.587)$

$= 448$ CFM

$= 32$ lb/MIN

$= 0.242$ KG/SEC

EXTRA 1 PSI FOR PRESS DROP =

PR = 1.655 @ .242 - .365 KG/SEC

CONVERT TO lb/MIN

+ 1PSI FOR PRESS DROP

FOR 597 CFM

626

$$\frac{597\ FT^3}{MIN} \left| \frac{lb}{14\ FT^3} \right. = 42.6\ \frac{lb}{MIN}$$

.33

1.47 PR

0.323 KG/SEC

FOR 397 CFM

$$\frac{397\ FT^3}{MIN} \left| \frac{lb}{14\ FT^3} \right. = 28.4\ lb/MIN$$

$$\frac{28.4\ lb}{MIN} \left| \frac{MIN}{60\ SEC} \right| \frac{KG}{2.2\ lb} = 0.215\ KG/SEC$$

POSSIBLE SP 30-94 (POSITIVE)

C 38-61

CFM OF BLOWER

DESIRED AIRFLOW RATE = $\begin{pmatrix}\text{BASIC}\\ \text{ENGINE}\\ \text{AIRFLOW}\end{pmatrix}(\text{PR})$

$= (424.6)(1.405)$

$= 597$ CFM

SIZE BLOWER FOR STREET MOTOR

TORQE PEAK + 25% = 4125 RPM

PLACE BLOWER PEAK EFFICIENCY @ 4125 RPM

$$= \frac{(254.5)(4125)(0.5)(0.93)}{1728}$$

$= 282.5$ CFM

NEW DESIRED AIRFLOW RATE

$= (282.5)(1.405)$

$= 397$ CFM

SECOND ITERATION

$$\text{TEMP GAIN} = \frac{\left(1.40^{0.28} - 1\right)(550)}{0.75}$$

$$= 72.4 \text{ F}$$

85% EFF INTERCOOLER

$$= (72.4)(1 - 0.85)$$

$$= 10.9 \text{ F}$$

DENSITY RATIO

$$= \frac{460 + 90}{460 + 90 + 10.9}$$

$$= 0.981$$

$$PR = \frac{400 \text{ HP}}{(300 \text{ HP})(0.981)(1.075)(0.9)}$$

$$= 1.405$$

$$= 5.95 \text{ PSI}$$

$$\text{DESIRED POWER} = (\text{STOCK HP})(\text{PR})\left(\begin{matrix}\text{DENSITY}\\ \text{RATIO}\end{matrix}\right)(E_V)\left(\begin{matrix}\text{DRIVE}\\ \text{POWER}\\ \text{EFF}\end{matrix}\right)$$

$$\Rightarrow \text{PR} = \frac{\text{DESIRED HP}}{(\text{STOCK HP})(\text{DENSITY RATIO})(E_V)\left(\begin{matrix}\text{DRIVE POWER}\\ \text{EFF}\end{matrix}\right)}$$

$$= \frac{400}{(300)(.984)(1.075)(0.90)}$$

$$= 1.40$$

$$\text{BOOST} = (14.7)(0.4)$$
$$= 5.88 \text{ PSI}$$

<u>450 HP</u>

$$\text{PR} = \frac{450}{(300)(.977)(1.075)(0.9)} \qquad E_V = 1.14$$

$$\text{PR} = 1.587 \qquad \text{PR} = 1.80$$

$$\text{BOOST} = 8.627 \text{ PSI} \qquad = 7.29 \text{ PSI}$$

$$\text{DENSITY RATIO} = \frac{\text{ORIGINAL } T_{ABS}}{\text{FINAL } T_{ABS}}$$

NON INTERCOOLED 90°F DAY

$$\text{DENSITY RATIO} = \frac{460 + 90}{460 + 90 + 61}$$

$$= .900$$

INTERCOOLED USING 85% EFF. INTERCOOLER

450 HP

$$\text{INTERCOOLER OUTLET TEMP} = (61)(1 - 0.85)$$

$$= 9.12\ F \qquad = 13.2F$$

$$\text{DENSITY RATIO} = \frac{460 + 90}{460 + 90 + 9.2}$$

$$= .984 \qquad = .977$$

$$PR = \frac{\text{DESIRED HP}}{\text{EXISTING HP}}$$

$$= \frac{400}{300} \qquad \frac{450}{300}$$

$$= 1.33 \qquad = 1.5$$

BOOST = $.33 \times 14.7$ PSI $\qquad = 7.35$ PSI

= 4.85 PSI

TEMPERATURE GAIN FROM SUPERCHARGER

$$\text{TEMP GAIN} = \frac{(PR^{0.28} - 1) \times T_{ABS}}{\text{COMPRESSOR EFFICIENCY}}$$

$$= \frac{(1.33^{0.28} - 1) \times 550}{0.75}$$

450 HP

= 61 °F $\qquad$ = 88 °F

SIZING THE COMPRESSOR

STREET ENGINE - PLACE THE PEAK COMPRESSOR WHEEL EFFICIENCY AT AN RPM ABOUT 25% HIGHER THAN THE TORQUE-PEAK RPM

ABZ TORQUE PEAK - 3300 RPM

+ 25% = 4125 RPM

OBJECTIVE - 400 HP FINAL

254.5 in^2

ABZ VOLUMETRIC EFFICIENCY = 93%

$$\text{VOLUMETRIC EFFICIENCIES RATIO} = \frac{\text{SUPERCHARGER } E_V}{\text{ENGINE } E_V}$$

$$= \frac{100\%}{93\%}$$

$$= 1.075$$

E_V FOR 88% ENGINE VOLUMETRIC EFF = 1.14

CONVERTING CFM INTO $\frac{lb}{MIN}$

$$\frac{lb}{MIN} = \frac{\frac{FT^3}{MIN}}{14\frac{FT^3}{lb}}$$

HEAT MADE BY SUPERCHARGER

$$(PR^{0.28} \times T_{ABS}) - T_{ABS}$$

WHERE:

PR = PRESSURE RATIO
T_{ABS} = AMBIENT TEMPERATURE ON THE ABSOLUTE SCALE ($°F + 460 = T_{ABS}$)

THERMAL EFFICIENCIES OF TYPICAL BLOWERS

ROOTS	50%
CENTRIFUGAL	75%
TWIN SCREW	70%

REAL HEAT MADE BY SUPERCHARGER

$$\frac{(PR^{0.28} \times T_{ABS}) - T_{ABS}}{\text{THERMAL EFFICIENCY}}$$

DRIVE POWER LOSSES

BELT LOSS - 3%
BELT EFFICIENCY = 97%

ADIABATIC LOSS - POWER LOST AS HEAT INSIDE THE BLOWER

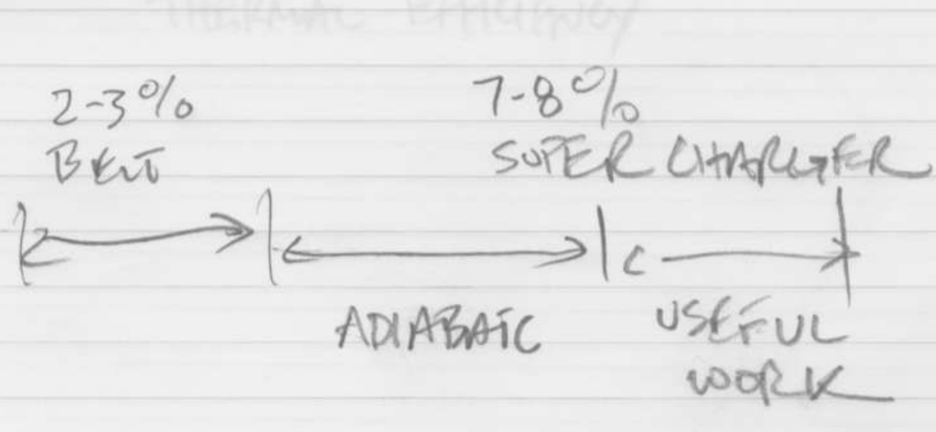
GENERALLY, 10% POWER IS LOST AT 10 PSI

3% BELT + 3-4% ADIABATIC + 3-4% USEFUL WORK

AT 5PSI - DRIVE POWER LOSSES = 7% (93%)

AT 15PSI - DRIVE POWER LOSSES = 14% (86%)

LOSSES



SUPERCHARGER VOUMETRIC EFFICIENCY

$$E_V = \frac{\text{ACTUAL VOLUME PUMPED}}{\text{THEORETICAL VOLUME IT COULD PUMP}}$$

FIXED DISPLACEMENT BLOWERS
= 92-95%

CENTRIFUGAL BLOWERS

FOR PURPOSES OF CALCULATIONS THE VOLUMETRIC EFFICIENCY OF A CENTRIFUGAL BLOWER CAN BE CONSIDERED 100% (IT PUMPS WHAT IT PUMPS)

PRESSURE RATIO IDEAL

$$PR = \frac{\text{DESIRED HP}}{\text{EXISTING HP}}$$

$$1.33 = \frac{400\ \text{HP}}{300\ \text{HP}}$$

DENSITY RATIO

THE DENSITY OF AIR VARIES INVERSELY WITH ABSOLUTE TEMPERATURE, IF AIR IS HEATED 10% ON THE ABSOLUTE SCALE, IT BECOMES 10% LESS DENSE. THE DENSITY RATIO IS THE RATIO OF BEFORE AND AFTER ABSOLUTE TEMPERATURES.

$$\text{DENSITY RATIO} = \frac{\text{ORIGINAL ABSOLUTE TEMP}}{\text{FINAL ABSOLUTE TEMP}}$$

ABSOLUTE TEMPERATURE = 460 + DEGREES F

USE AMBIENT & INTERCOOLER OUTLET FOR CALCULATIONS

AIRFLOW RATE ABZ

$$\text{AIRFLOW RATE} = \frac{CID \times RPM \times 0.5 \times E_V}{1{,}728}$$

WHEN $E_V = 85\%$ $= \dfrac{254.5 \times 6200 \times 0.5 \times 0.85}{1728}$

85% = 388 CFM
86% = 392.6 CFM

WHEN EV = 88% = 401.8 CFM

WHEN EV = 90% = 410.9 CFM

92% = 420.0 CFM

94% = 429.2 CFM

95% = 433.7 CFM

USE 93% FOR CALCS = 424.6 CFM

TESTING

AMBIENT TEMPS UNDER HOOD

FUEL

INJECTOR FLOW
FUEL PUMP FLOW
INJECTOR DUTY CYCLE

FUEL INJECTION

TIME FOR ONE REVELOUTION
@ 6200 RPM

$$= \frac{60\ \text{SEC}}{\text{MIN}} \left| \frac{1\ \text{MIN}}{6200\ \text{REV}} \right.$$

$$= 0.0097\ \text{SEC/REV}$$

$$= 9.7\ \text{MSEC}$$

NEED TO MEASURE REDLINE
PULSE DURATION

HEAT MADE BY COMPRESSION RATIO

TEMP GAIN = $(CR^{0.28} - 1) \times T_{ABS}$

$= (10.8^{0.28} - 1) \times 550$

$= 520$ ° ABSOLUTE

ASSUME 90 F AMBIENT

90F = 90 + 460 = 550 ABSOLUTE

AMBIENT	550
HEAT MADE BY COMP. RATIO	520
TOTAL TEMP	1070

REFERENCE

9:1 CR
= 1018 TOTAL TEMP

11:1 CR
= 1076 TOTAL TEMP

Rotrex™ Compressor Unit C38 - 61

Version: 2003-04-NLO

Technical Data Sheet

General Description

The C38 is a range of centrifugal superchargers for compact combustion engine applications from 3 litres and up to approximately 6 litres.
The compact size enables a very flexible supercharger installation particularly on compact engine applications, where weight and size is essential.

The supercharger exhibits excellent efficiency, as well as very low noise and vibration characteristics.

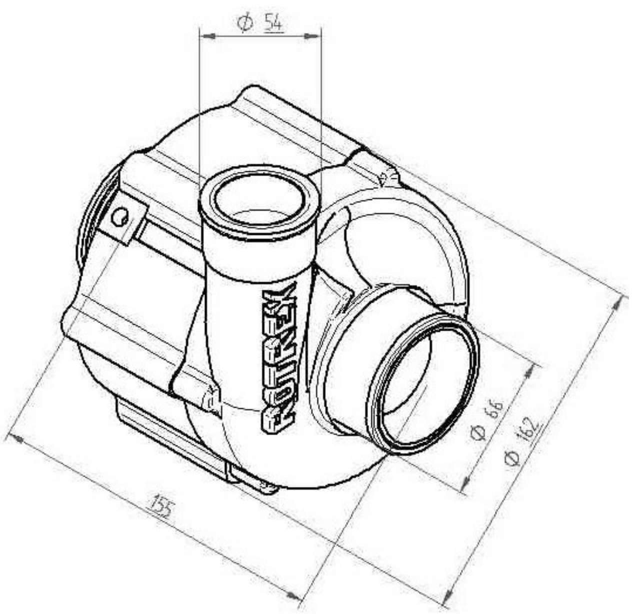
Applications

The C38 – 61 trim is designed for four stroke gasoline engines with a supercharged output range of 300 to 550 Bhp.

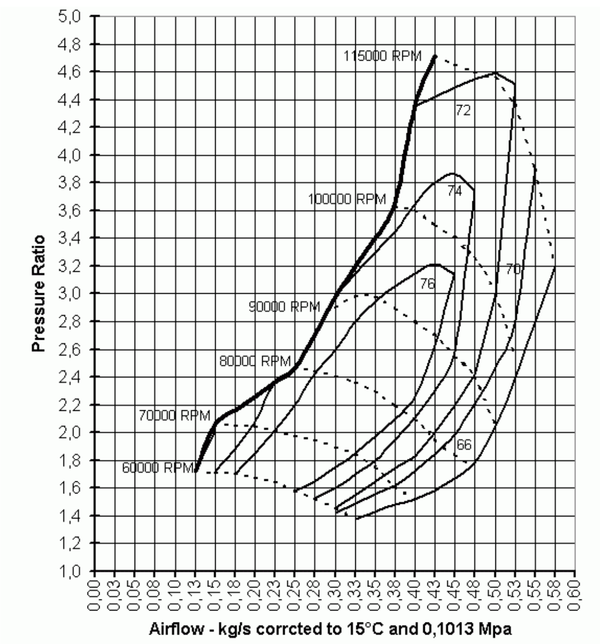
The C38 – 61 replaces the SP30-104 unit.

A 6 to 9 ribbed poly-V belt, enabling a low cost durable and efficient transmission, drives the supercharger.

Dimensions



Flow chart C38 trim 61



Oil system

The supercharger has an integrated double oil-pump with external oil reservoir, filter and optional cooler.

Only special traction fluid should be used.
Traction fluid is available from Rotrex.

Maximum oil inlet temperature: 80°C (176°F)
The requirement for oil cooling will depend on the individual application.

Gear unit

Ratio:	7,5 : 1
Gear efficiency:	92-99%
Pulley size:	70 mm to 110 mm
Max input axle speed:	12.000 rpm
Max impeller speed:	90.000 rpm

ROTREX A/S Skelmosevej 1 DK-2500 Valby Denmark
Tel. (+45) 36 15 91 00 Telefax (+45) 36 16 65 05
Internet: www.rotrex.eu.com