Intake and Exhaust Manifold Design: Part 1

John Kerr
Junior Physics Major

Outline

- Purpose and background of the project
- Intake manifold design
- Exhaust manifold design
- Proto-type design
- Testing and Goals
- Conclusion

Purpose

- Design an intake manifold to suite the high rpm function of my race car.
- Manifold must produce and hold power to at least 9500 RPM and also must have a usable power band.
- The manifold must be pleasing to look at and fit inside the engine bay of the race car.

What is an intake manifold?

- An intake manifold's job is to guide the air into the cylinder head.
- In a fuel injected car a throttle plate or throttle body is attached to one end and is used to control the air flow entering the manifold.
- Many race engines use a separate throttle plate for each cylinder opposed to a street driver car which normally uses one.

Parts to the manifold

- Plenum
  - The plenum is the big usually circular part of the manifold. All of the runners are fed by the plenum.
  - Plenum size should be 50-70% of the actual engine displacement.

Runners

- The runners stem from the plenum and are connected to the cylinder head.
- They have a tapered shape starting large at the plenum and gradually get smaller near the cylinder head.
- Variable runner length effects the power band of your car. (Explained in detail later)
- Short runners and wide are optimal for higher engine function and Long and narrow runners are optimal for low-mid rpm function.

Throttle Body or Throttle Plate

- Controls the air flow into the intake plenum.
- Size of the throttle body effects the speed at which the air enters.
- The air velocity should be kept at approximately at 300 ft/sec for smooth throttle response.
  - V = (Airflow rate / Area of section)

Fuel Injector Location

- Two main guidelines to follow
  - Aim directly down the center of the port, located on each runner.
  - Discharge at a point where velocity is greatest and at an angle of less than 20* with respect to the runner.
    - **High velocity helps to atomize the fuel with the air. Also decreases the chance of fuel to puddle inside the manifold.**
    - **A secondary injector can also be added and it can be placed so it discharged upstream, BUT the airflow must be large. This can also help in atomization.**

Ram Air Theory

- This theory is used to help explain the boost at a certain RPM that is noticed when varying runner lengths.
- To describe how this works we have to take into account that mass air flow can be explained if you characterize it as a sound wave and its corresponding frequencies.
- You can think of the air as pulsating up and down the runner as a wave, not just entering the cylinder head at will.


COLUMN OF AIR-FUEL
WANTS TO KEEP MOVING

- When the piston drops in a naturally aspirated engine, it creates a low pressure area inside the cylinder. This allows the atmospheric pressure to enter the valve once it opens. But the air does not just stop once the valve shuts. The air (as a sound wave) gets reflected back up the intake manifold runner which in return hits the plenum and is reflected back down the runner.
- The plenum acts as a resonance chamber. Each reflection from the from the resonance chamber adds more (energy,tone,amplitude) to the sound wave.
- The idea is to get these maximized waves to the valves so they enter the motor with increased energy, which in some cases can be over atmospheric pressure.

Example Calculation

- Engine B18C1 DOHC 1.8 VTEC
- Intake valve open for 230* of crank rotation
- Speed of sound 1,125 ft/sec
- Runner Length = 6.9”
- Crank rotates 720* for 1 intake cycle
- Max Torque estimation 8000 RPM

David Vizzard's Rule: Runner Length

- Begin with 17.8cm and a max torque of 10,000 RPM.
- For every 1000 RPM you want max torque to be lower, add 4.3cm to the runner length.
- Example: Max tq at 6000 RPM
  - **L = 17.8 +(4x4.3) = 35 cm or 13.7"**

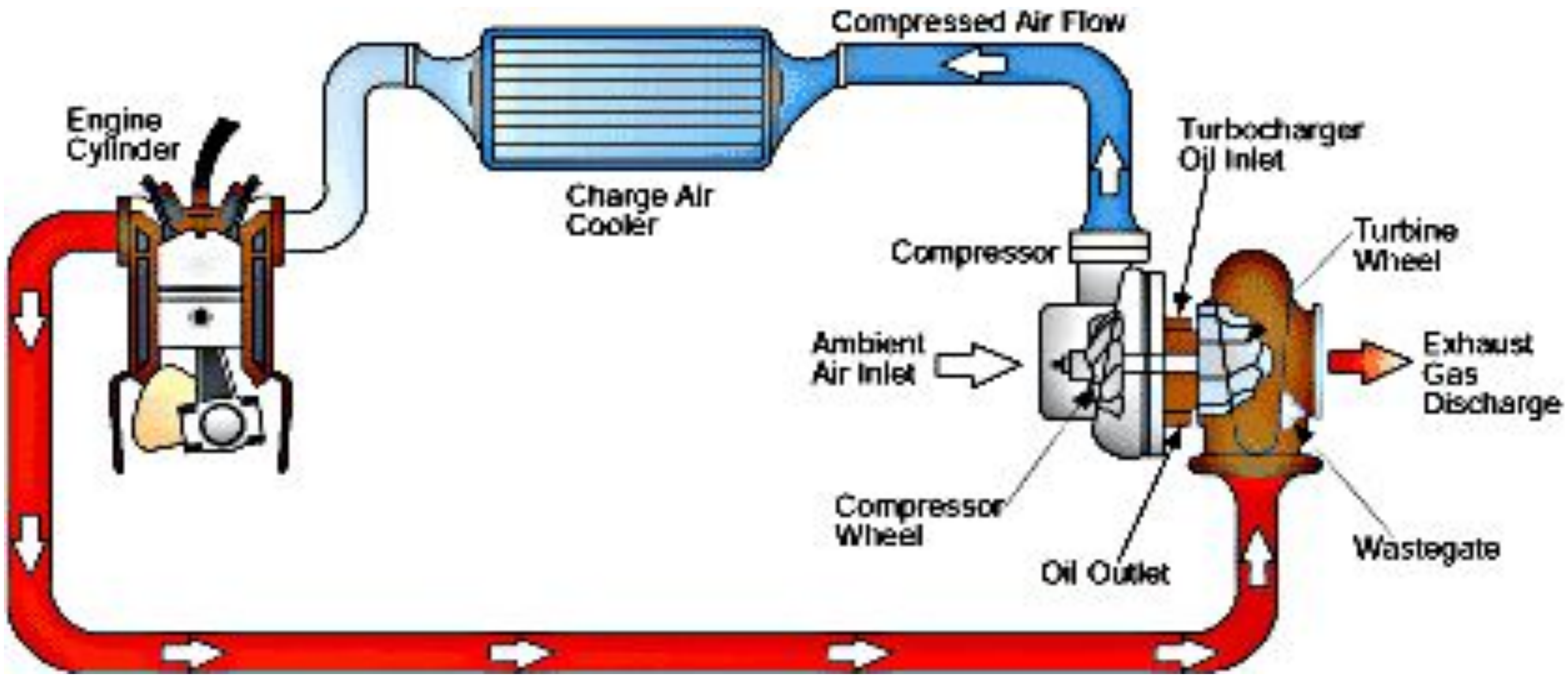
http://www.rbracing-rsr.com/runnertorquecalc.html

Helmholtz Approximation

- RPM = = 218,280 x [SQRT (S/[L x V])] x [SQRT { (CR-1)/ (CR+1) }]
- S= Runner Area
- L= Runner Length
- CR = Compression Ratio
- V= Displacement per cylinder
- This approximation uses the resonance chamber, just like the ram air theory.

What is a turbo?

- A turbocharger is used on race engines to overcome 100% volumetric efficiency. This can’t be done without some sort of forced induction into the engine. It basically adds more air to the motor.
- It is driven by exhaust gases from the motor.


Compressed Air Flow
Engine
Cylinder
Charge Air
Cooler
Turbocharger
Oil Inlet
Compressor
Turbine
Wheel
Ambient
Air Inlet
Exhaust
Gas
Discharge
Compressor
Wheel
Oil Outlet
Wastegate

Overview of Turbo Manifold Design

- **Goal of the manifold is to direct the exhaust gases through the turbine side of the turbo.**
- **Manifolds are commonly built of 304 stainless steel. It is strong and resists cracking at the high temperatures that the turbo manifold will see.**
- **Manifold should have wastegate priority. The wastegate is what regulates the boost pressure of the compressor side of the turbo.**
- **Volume of runners and runner length should be optimized. For the test vehicle, a long runner manifold such as a top mount or a ramhorn manifold should be used, with fluid bends not sharp angles.**

Examples

Short Tubular – Good Spool, Lacks Top End power.

Tubular Ramhorn – Slower Spool, Great Top End Power.

Prototype Intake Manifold Design

- **Explain plenum size of Victor X manifold and runner length/shape.**
- **Going to use a Edelbrock 65mm throttle body on both intake manifolds.**
- **Plenum size to be 1.25% of the motor size. Which would put the plenum size to be around 2.5L**
- **Utilizing constant surface area through the entire runner length.**
- **Runner/Plenum intersection will have a bell-mouth shape given by the relation of throat diameter to the radius of the inlet to the runner. The relation is Inlet diameter = 3 x Runner Diameter.**

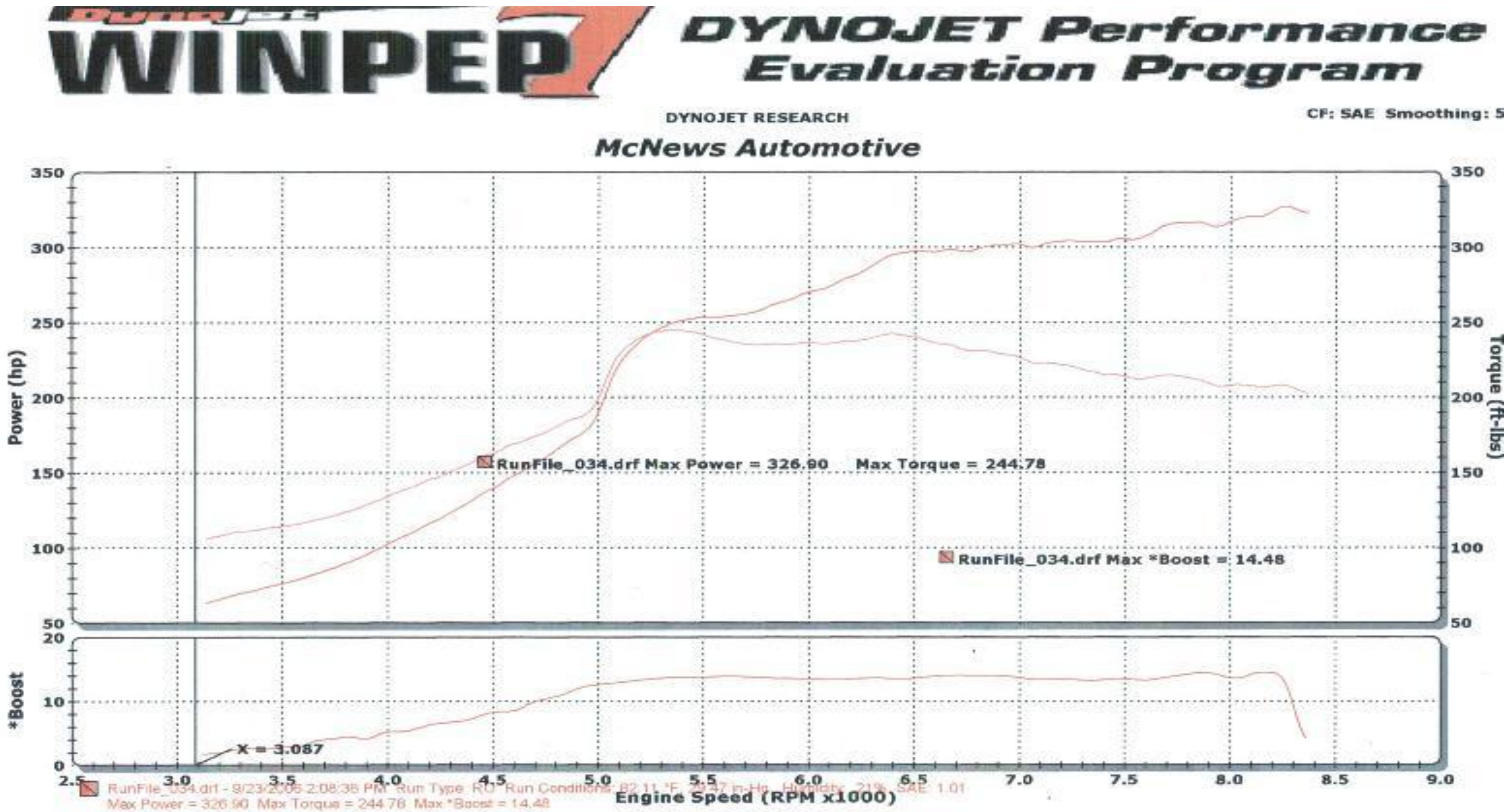
Testing

- The manifold will be tested on my race car. The motor will be a Sleeved 2.0L LS/VTEC motor, with a built cylinder head and forged bottom end allowing for high rpm power and the ability to withstand high boost pressures.
- The test will be done against my Victor X manifold at 14, 20 and 25 psi.
- The test will be monitored in a fully controlled environment on a chassis dyno.

- Both setups will be tuned with Neptune EMS by me.
- Data logs will be kept of the various engine sensors, such as manifold pressure, rpm, intake temperature, and air/fuel ratio. These logs will help in the comparison of each manifold.
- Dyno graphs will be used to compare the torque/horsepower output of each manifold. To note where each produces the most power.

- To read the dyno graph you will notice horsepower and torque are on the Y-axis and RPM is on the X-axis.
- As you can see Horsepower is a function of the engine torque. The equation is
  - **HP = (RPM x TQ)/ (5252)**
  - **When HP and Tq are equal, the RPM=5252**
- The number 5252 is derived by the unit for 1 HP. 1 HP= 33,000 ft-lbs/min. To get 5252 you divide 33,000 by (2xPi).

Example Dyno Graph



Dyno Video

The Test Subject

http://www.j-k-tuning.com/images/Dragcar.html

References

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