Summary of DIE (Dynamic Intake Effect) Analysis

Synopsis of the DIE

The DIE phenomenon is produced by the opening and closing of the intake ports of the 13B NA twin rotary engine. These port events generate a Finite-Amplitude Wave (FAW) at the intake port of one rotor, which races through the intake manifold and terminates near the intake port of the second rotor. Under proper conditions, the kinetic energy of the FAW traveling at the speed of sound is transformed into a local manifold pressure increase of considerable magnitude. FAW studies have shown this wave may generate local pressure in the range of from 12-20 psi above ambient. The basic requirement is there be an airflow path from the intake port of one rotor to the intake port of the second rotor.

Figure 5.0 of the Mazda SAE Paper 900036 (Kindly provided by Paul Lamar) shows the timing required of this pulse as well as the resulting intake manifold pressure increase. Basically the DIE timing relationship is quite simple.

The optimum DIE condition requires that the time required (Tr) for the pulse to transverse the manifold be equal to the time available (Ta) for it to travel that distance and arrive just before the second intake port closes.

The DIE timing requirement then implies that:

$$DIE \Rightarrow Ta = Tr$$

Achieving this timing then means there is an increase in localized intake manifold pressure just before the port closes. This increase pressure in the intake manifold opposes the reversion effect (flow of air/fuel mixture back out of the closing but still open port as the rotor comes up on its compression stroke) and the end result is more power producing mixture remains in the combustion chamber. Another way to think of the results of the pressure increase is that it in effect temporarily increases the volumetric efficiency of the induction system.

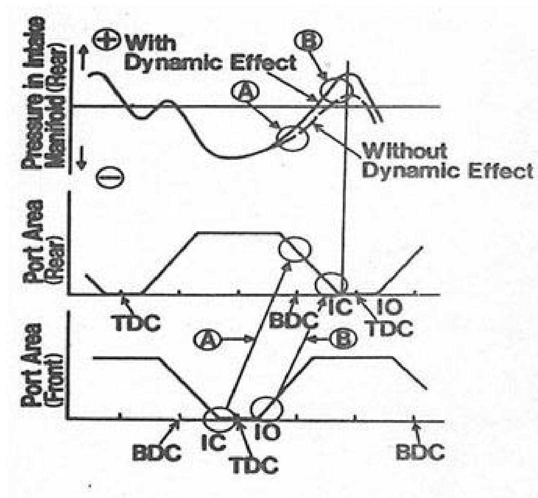

Fig.5 Pressure wave transmission timing of dynamic effect intake system and its effect

The Time Required (Tr) is defined by:

$$Tr = L/Vp$$

"L" being the port to port length of the intake manifold and "Vp"
being the speed of sound of the FAW at the specified manifold air temperature (180F is used in the analysis)

The Time Available (***Ta***) is defined by:

$$Ta = Ad/Ars$$

Ad is the angular difference in eccentric-shaft-referenced degrees between the opening of the intake port of the front rotor and closing of the rotor intake port of the rear rotor as shown by pulse "B" in Fig.5 ***Ars*** is the angular rotational velocity (degrees per second) of the eccentric shaft at the specified RPM.

Ad can be found by establishing a common reference point at the first "TDC" tic of the rear rotor shown in Fig 5 and noting that IC for the rear rotor is 270+IC and noting that IO for the front rotor is 180+IO from the common reference point. (Note each tic mark is 90 degree of eccentric shaft rotation). Therefore,

$$Ad = (270+IC)-(180+IO)$$

IC is the closing Intake port timing specification for the port being considered. IO is the Opening Intake Port timing specification.

Ars, the eccentric shaft angular rotation velocity, is equal to

$$Ars = 360*(RPM/60)$$

Therefore we can now find the Time Required (Ta)

$$Ta = Ad/Ars = [(270+IC)-(180+IO)]/(360*(RPM/60))$$

However, Ta must be adjusted for the time it takes to generate the FAW pulse peak of duration (PD) which is 1/2PD and for it to arrive sufficiently before the port closes (also 1/2PD) for the total energy of the pulse to contribute to the DIE pressure increase. This requires ***Ta*** to be reduced by a total of ***PD***. Taking PD in eccentric shaft degrees we now have the complete Ta equation.

$$Ta = Ad/Ars = [(270+IC)-(180+IO)-PD]/(360*(RPM/60))$$

The DIE premise is that Ta = Tr, therefore for the DIE condition we have:

$$DIE \Rightarrow Tr = Ta$$

$$Tr = L/Vp$$

$$Ta = [(270+IC)-(180+IO)-PD]/(360*(RPM/60))$$

Since Tr and Ta are equal in time at the optimum DIE RPM, we can solve for the length (L) required for that RPM

$$L/Vp=[(270+IC)-(180+IO)-PD]/(360*(RPM/60))$$

or solving for L in inches

$$L=12*Vp*[(270+IC)-(180+IO)-PD]/(360*(RPM/60))$$

L Port to port Length (inches)
Vp Speed of Sound of FAW (feet/sec)
IC, IO and PD in Eshaft referenced Degrees (Degrees)

This is a parametric equation that can be used to generate unique curves each representing the ***Ta=Tr*** condition for the given Vp, IC, and IO as parametric constants and L the dependent variable of independent variable RPM. PD is a non-linear function of RPM and remains on the right side of the equation. PD will range from approx 30 E shaft Degrees at 3500 rpm to approx 15 E shaft degrees at 6500 rpm. More work is being focused on the PD function.

Attached are parametric curves for the rotary engines most common port timing and manifold temperature (180F). Note if your engine's porting is not as specified on the graphs or the manifold temp is not 180F, then the curves shown are not appropriate for your engine. Just how inappropriate, of course, depends on how great the variance.

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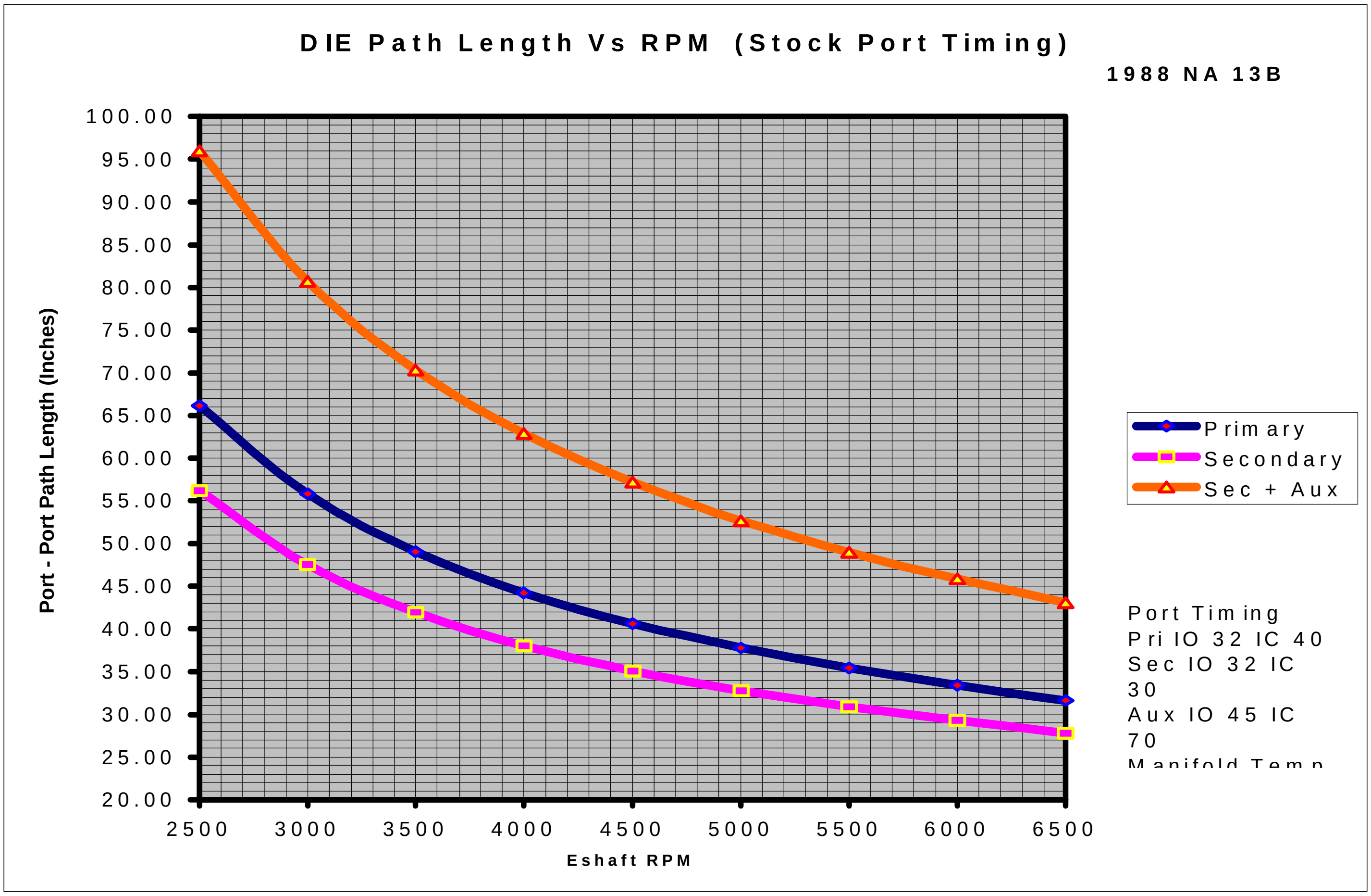
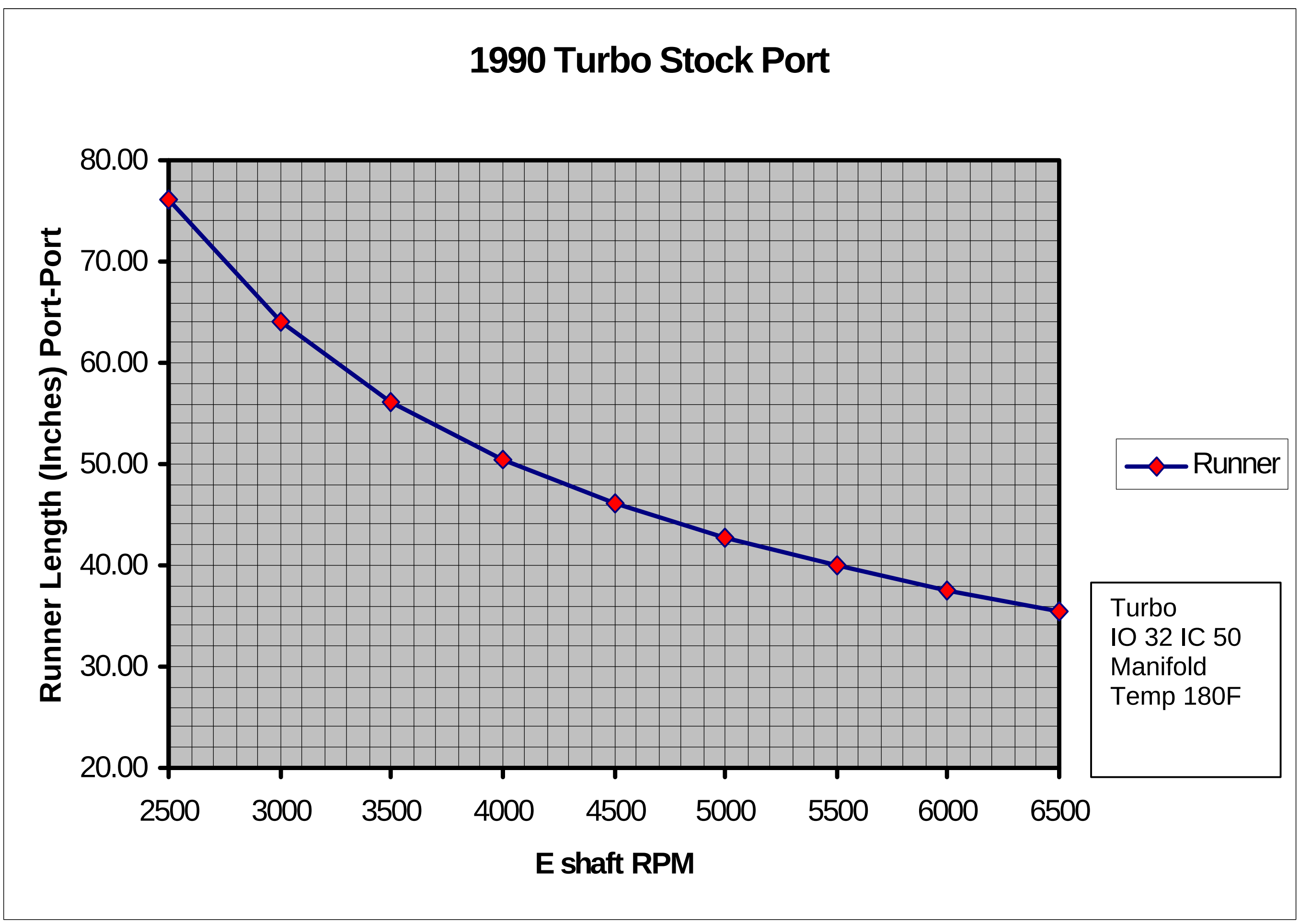
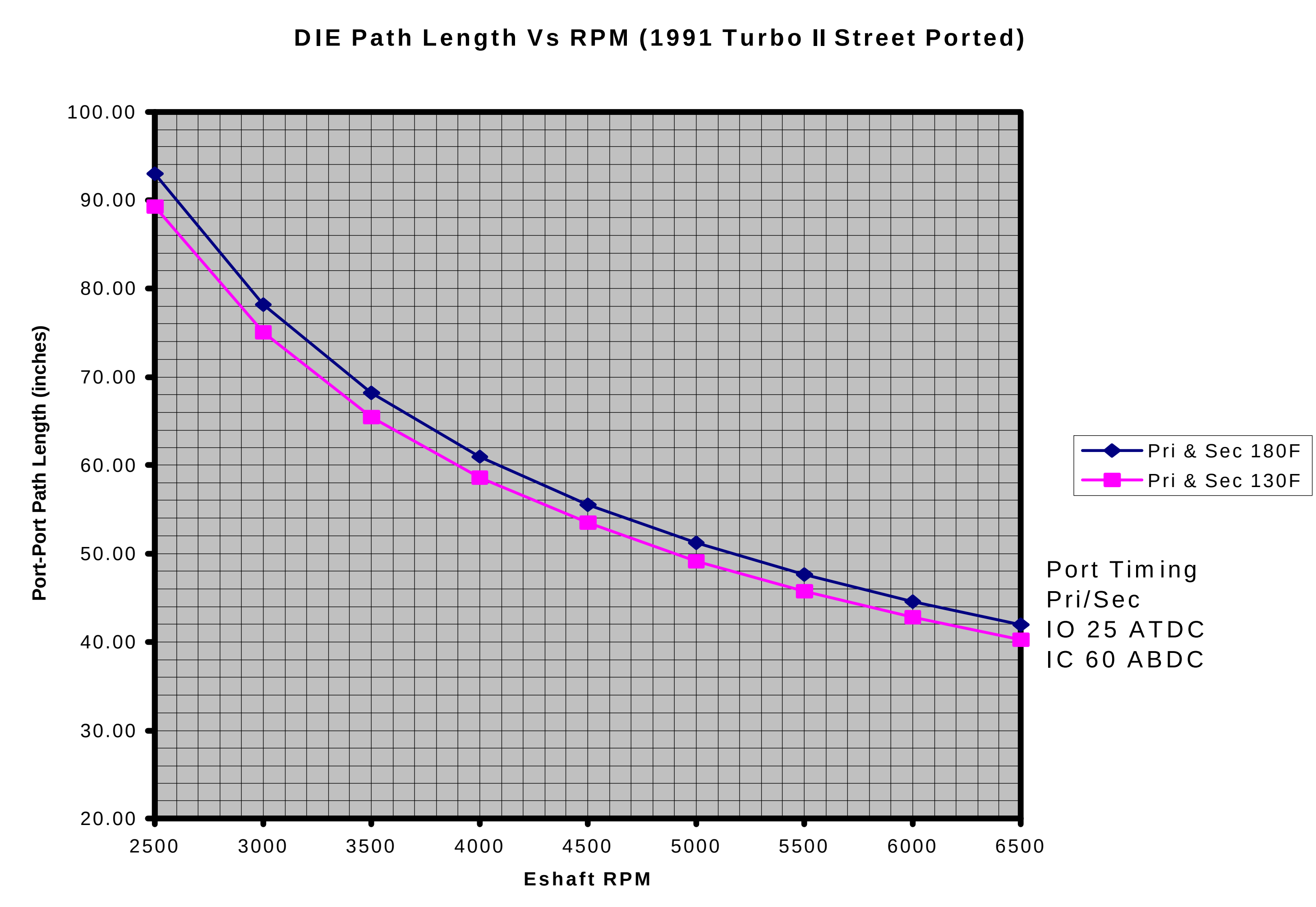

DIE Path Length Vs RPM (Stock Port Timing)
1988 NA 13B
Port - Port Path Length (Inches)
100.00
95.00
90.00
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
20.00
2500
3000
3500
4000
4500
5000
5500
6000
6500
Eshaft RPM
Primary
Secondary
Sec + Aux
Port Timing
Pri IO 32 IC 40
Sec IO 32 IC 30
Aux IO 45 IC 70


1990 Turbo Stock Port
Runner Length (Inches) Port-Port
80.00
70.00
60.00
50.00
40.00
30.00
20.00
2500
3000
3500
4000
4500
5000
5500
6000
6500
E shaft RPM
Runner
Turbo
IO 32 IC 50
Manifold
Temp 180F



This graph for a Racing Street Ported 13B turbo block and shows the effect on the parametric curve for a 50F decrease in intake manifold air temperature. A decrease in manifold air temperature has the effect of lowering the curve and vice versa. This of course means that the DIE rpm point will vary as the intake manifold air temperature varies. The automobile has a coolant temperature stabilized intake manifold where as most aircraft installations do not. This is one complicating factor in employing DIE in aircraft. Also, a varible or "switchable" length manifold would be ideal in that you could "tune" the manifold to get the DIE effect at the rpm you desired for a particular regime of operation. One could envision a "take-off", "Climb" and "Cruise" position of such a "variable" manifold.