Adapting Fuel Injector Data with a Manifold Referenced Fuel Pressure Regulator

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A popular change for many high-performance engine builds is to include a completely new fuel system that improves the delivery of fuel (and PRESSURE!) to the injectors. We know that even high flow injectors won't get the job done if we can't keep pressurized fuel behind them for every shot. Many modern vehicles have what's known as a "dead headed" fuel system where the pressure regulator is built into either the fuel pump module in the tank or in the filter that is still near the rear of the vehicle, a long way from the engine and fuel rail. This is usually done by the OEM to reduce the fuel heating associated with repeated trips from the tank to the engine compartment and back to the tank, which in turn leads to better control of their fuel tank vapor pressure. In these systems, we can see significant drop in rail pressure at high flow rates due to head losses along the length of the fuel line.

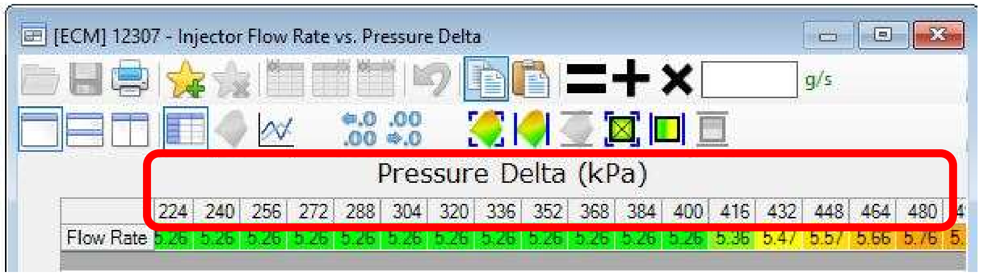
The solution in many cases is replace the factory "dead headed" system with an active fuel pressure regulator. By moving the regulator to a point after the fuel rail, we can automatically compensate for any head losses at higher flow rates. We also open up another great option: the ability to adjust rail pressure relative to Manifold Absolute Pressure (MAP). When we connect a **pressure reference line** from the intake plenum to the fuel pressure regulator, we now move the two in sync with each other.

When the engine runs under vacuum, rail pressure is reduced slightly. This effectively reduces the flow rate of the injector compared to what it would have been with a static rail pressure. This can be very handy when trying to control small pulse widths and fuel masses from high flow rate injectors at idle and cruise.

On the other end of the pressure spectrum, making boost in the intake plenum pushes harder on the fuel pressure regulator's diaphragm which increases rail pressure by a corresponding amount. This means that if we make 10psi of intake boost (above atmospheric), we would have a loss of DELTA pressure across the fuel injector in a dead headed system because the boost is effectively working against fuel rail pressure when it comes time to flow through the injector. Adding the manifold referenced regular increases the rail pressure by the same 10 extra PSI, preserving the original flow rate of the injector, even when boost is present. Rail pressure is higher, but the DELTA pressure across the injector remains the same and we don't lose flow rate when we need it most.

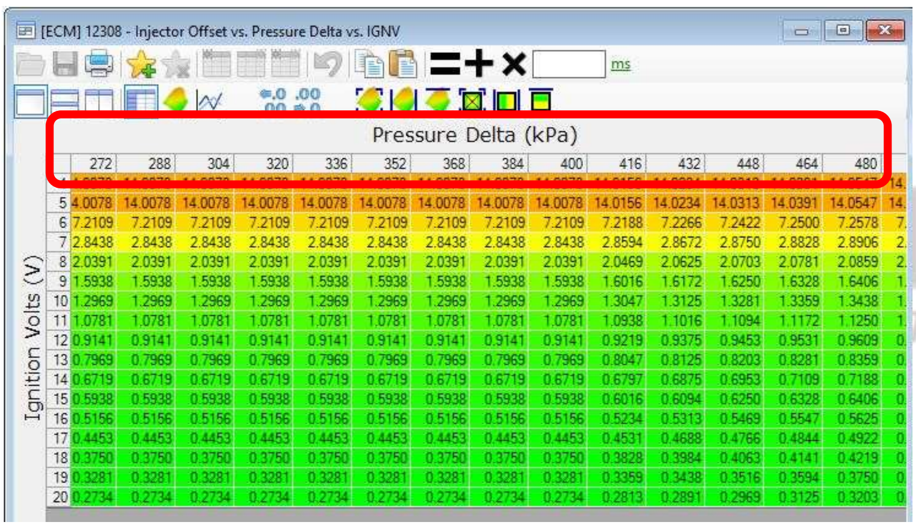
Blah blah blah! Great theory, Greg, but where do we update our calibrations?

By now, the performance aftermarket has become pretty savvy to the need for good fuel injector characterization data. Rightly so, we only been preaching exactly that for about 16 years as of this writing. Even better, we have pushed hard at Calibrated Success to make that data more accessible to the industry through testing, coaching injector manufacturers and resellers and even making our own test bench that easily generates injector characterization data in the exact format needed by calibrators using popular aftermarket ECU tools.



	Pressure Delta (kPa)																	
	224	240	256	272	288	304	320	336	352	368	384	400	416	432	448	464	480	4
Flow Rate	5.26	5.26	5.26	5.26	5.26	5.26	5.26	5.26	5.26	5.26	5.26	5.26	5.36	5.47	5.57	5.66	5.76	5.

When one looks at the fuel injector characterization data, differences can be seen in regard to operating pressure, delta pressure, or MAP/vacuum. This is because the OEMs are not stupid. They know that their rail pressure is held constant by the mechanical regulator in the tank, but the MAP moves around, so they build **tables in the ECU** that compensate for the effects of this pressure change (within the bounds of pressures they expect their stock engines to run). Some of these tables are multipliers, others adders or just new values that correspond to the different pressures. The example to the right here happens to be a GM where they reference rail "Pressure Delta" which is simply the ASSUMED rail pressure of 400kPa plus the amount of vacuum (Baro-MAP) in the manifold. So WOT on a naturally aspirated engine (MAP=Baro) means a pressure delta of roughly 400kPa, and idling at a MAP of 40kPa would mean a pressure delta of (400 + (100-40)) or 460kPa. These systems can even work when an aftermarket supercharger is installed as long as the values in the boost region (below 400kPa Delta in this case) are populated with good data.

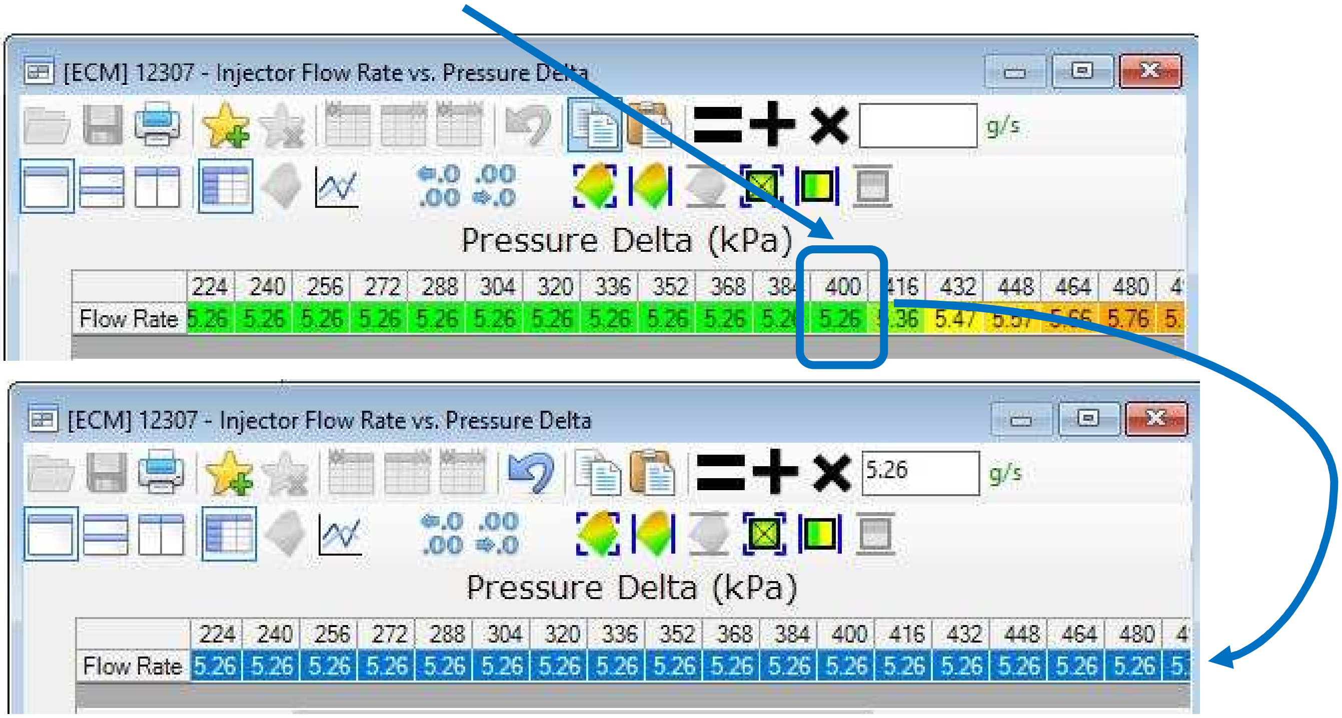


Ignition Volts (V)	Pressure Delta (kPa) 272	288	304	320	336	352	368	384	400	416	432	448	464	480	
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.
5	4.0078	14.0078	14.0078	14.0078	14.0078	14.0078	14.0078	14.0078	14.0078	14.0156	14.0234	14.0313	14.0391	14.0547	14.
6	7.2109	7.2109	7.2109	7.2109	7.2109	7.2109	7.2109	7.2109	7.2109	7.2188	7.2266	7.2422	7.2500	7.2578	7.
7	2.8438	2.8438	2.8438	2.8438	2.8438	2.8438	2.8438	2.8438	2.8438	2.8594	2.8672	2.8750	2.8828	2.8906	2.
8	2.0391	2.0391	2.0391	2.0391	2.0391	2.0391	2.0391	2.0391	2.0391	2.0469	2.0625	2.0703	2.0781	2.0859	2.
9	1.5938	1.5938	1.5938	1.5938	1.5938	1.5938	1.5938	1.5938	1.5938	1.6016	1.6172	1.6250	1.6328	1.6406	1.
10	1.2969	1.2969	1.2969	1.2969	1.2969	1.2969	1.2969	1.2969	1.2969	1.3047	1.3125	1.3281	1.3359	1.3438	1.
11	1.0781	1.0781	1.0781	1.0781	1.0781	1.0781	1.0781	1.0781	1.0781	1.0938	1.1016	1.1094	1.1172	1.1250	1.
12	0.9141	0.9141	0.9141	0.9141	0.9141	0.9141	0.9141	0.9141	0.9141	0.9219	0.9375	0.9453	0.9531	0.9609	0.
13	0.7969	0.7969	0.7969	0.7969	0.7969	0.7969	0.7969	0.7969	0.7969	0.8047	0.8125	0.8203	0.8281	0.8359	0.
14	0.6719	0.6719	0.6719	0.6719	0.6719	0.6719	0.6719	0.6719	0.6719	0.6797	0.6875	0.6953	0.7109	0.7188	0.
15	0.5938	0.5938	0.5938	0.5938	0.5938	0.5938	0.5938	0.5938	0.5938	0.6016	0.6094	0.6250	0.6328	0.6406	0.
16	0.5156	0.5156	0.5156	0.5156	0.5156	0.5156	0.5156	0.5156	0.5156	0.5234	0.5313	0.5469	0.5547	0.5625	0.
17	0.4453	0.4453	0.4453	0.4453	0.4453	0.4453	0.4453	0.4453	0.4453	0.4531	0.4688	0.4766	0.4844	0.4922	0.
18	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3828	0.3984	0.4063	0.4141	0.4219	0.
19	0.3281	0.3281	0.3281	0.3281	0.3281	0.3281	0.3281	0.3281	0.3281	0.3359	0.3438	0.3516	0.3594	0.3750	0.
20	0.2734	0.2734	0.2734	0.2734	0.2734	0.2734	0.2734	0.2734	0.2734	0.2813	0.2891	0.2969	0.3125	0.3203	0.

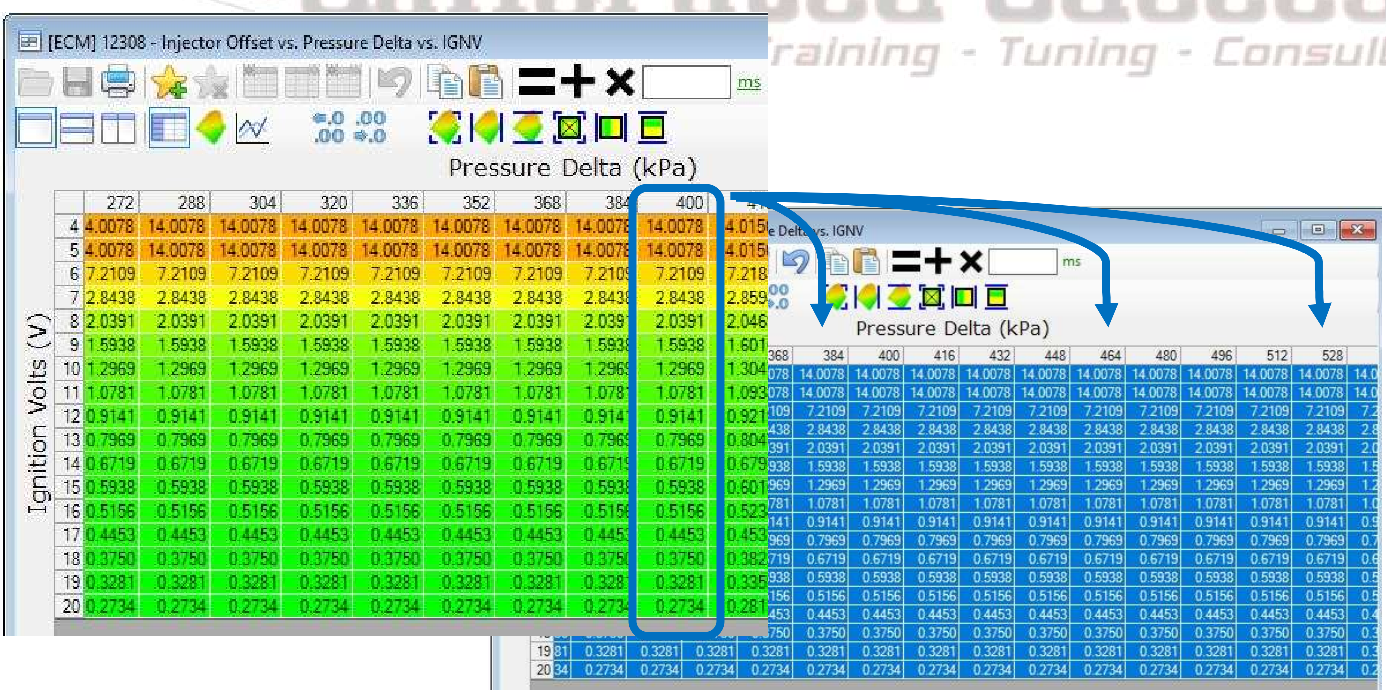
Now we can go back to our high-performance fuel system example, where our new hardware breaks this ASSUMED relationship in the ECU/calibration. Yes, adding a manifold referenced regulator is generally good for fuel control, we just need to make a couple simple tweaks to work with it on modern ECUs. Since the ECU is always ASSUMING that the pressure delta is moving, it will grab the injector data from different cells when in reality, it should just keep using the same value because the physical pressure delta has not changed.

The fix is simple. As we showed in our training videos (available over at https://cartrainingonline.com/), when you import your known good injector data, you will simply only use the data from the reference pressure where the new mechanical manifold referenced fuel pressure regulator has been set. So if this is a typical GM or Chrysler vehicle that would be 400kPa (or 0kPa vaccum on the earlier models), with a Ford Coyote it's 55psi. All you have to do is copy those same values from the reference pressure into ALL other pressure columns or rows as show next.

For a GM flow rate, take the **reference value** and use it for the whole table:



For a GM injector offset table, just do the same by column. All rows of various pressures will have the same value for a given voltage now because delta pressure is not really changing.



For a Ford controller where it is expecting a static reference of 55psi, you would simply copy the multipliers from the 55psi row to all other rows: (Do NOT do this for Electronic Returnless Fords with a Fuel Rail Pressure sensor)

Calibration Summary

Sampled Injection Pressure 398.7 kPa 57.8 psi

ALOSL	0.031152303	lb/sec
AHISL	0.016893389	lb/sec
FUEL_BKPT	0.0000187	lb
MINPW	0.1888	ms

FNPW_LSCOMP	
30	0.7203
39.15	0.8228
50	0.9299
55	0.9753
60	1.0186
70	1.1003

FNPW_BKCOMP	
30	0.7203
39.15	0.8228
50	0.9299
55	0.9753
60	1.0186
70	1.1003

FNPW_OFFSET	
6	3.468
8	2.482
10	1.826
11	1.585
12	1.389
13	1.229
14	1.099
15	0.993

FNPW_HSCOMP	
30	0.7203
39.15	0.8228
50	0.9299
55	0.9753
60	1.0186
70	1.1003

FNPW_OFFCOMP	
30	0.868742
39.15	0.913967
50	0.967594
55	0.992307
60	1.01702
70	1.066446

ALOSL	0.031152303	lb/sec
AHISL	0.016893389	lb/sec
FUEL_BKPT	0.0000187	lb
MINPW	0.1888	ms

FNPW_LSCOMP	
30	0.9753
39.15	0.9753
50	0.9753
55	0.9753
60	0.9753
70	0.9753

FNPW_BKCOMP	
30	0.9753
39.15	0.9753
50	0.9753
55	0.9753
60	0.9753
70	0.9753

FNPW_OFFSET	
6	3.468
8	2.482
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13	1.229
14	1.099
15	0.993

FNPW_HSCOMP	
30	0.9753
39.15	0.9753
50	0.9753
55	0.9753
60	0.9753
70	0.9753

FNPW_OFFCOMP	
30	0.992307
39.15	0.992307
50	0.992307
55	0.992307
60	0.992307
70	0.992307

With a Chrysler vehicle, it's even simpler because you only have to do this once with the Inj PW Offset table:

Inj PW Offset

kPa	6.0	7.0	8.0	10.0	12.0	14.0	15.8	15.8
0	3.464	2.928	2.482	1.824	1.390	1.098	0.926	0.926
20	3.540	2.990	2.533	1.858	1.412	1.113	0.936	0.936
40	3.618	3.053	2.585	1.892	1.435	1.128	0.947	0.947
80	3.780	3.186	2.693	1.964	1.483	1.160	0.969	0.969
100	3.864	3.254	2.749	2.001	1.507	1.177	0.981	0.981

ms	8.0	9.5	11.0	12.0	12.8	13.5	14.0	14.7
-80	2.293	1.827	1.483	1.306	1.194	1.099	1.042	0.969
0	2.482	1.967	1.587	1.390	1.266	1.161	1.098	1.017
40	2.585	2.042	1.642	1.435	1.304	1.195	1.128	1.043
62	2.644	2.085	1.674	1.461	1.327	1.214	1.146	1.058
84	2.704	2.130	1.707	1.488	1.350	1.234	1.163	1.073

ms	5.0	6.0	7.0	8.0	9.0	10.1	12.1	14.1
250	3.504	2.953	2.509	2.141	1.842	1.584	1.230	0.993
300	3.701	3.112	2.640	2.248	1.929	1.654	1.276	1.024
400	4.132	3.464	2.928	2.482	2.120	1.808	1.379	1.092
500	4.623	3.864	3.254	2.749	2.337	1.982	1.495	1.169
550	4.893	4.084	3.434	2.895	2.456	2.078	1.559	1.212

Inj PW Offset

kPa	6.0	7.0	8.0	10.0	12.0	14.0	15.8	15.8
0	3.464	2.928	2.482	1.824	1.390	1.098	0.926	0.926
20	3.464	2.928	2.482	1.824	1.390	1.098	0.926	0.926
40	3.464	2.928	2.482	1.824	1.390	1.098	0.926	0.926
80	3.464	2.928	2.482	1.824	1.390	1.098	0.926	0.926
100	3.464	2.928	2.482	1.824	1.390	1.098	0.926	0.926

ms	8.0	9.5	11.0	12.0	12.8	13.5	14.0	14.7
-80	2.482	1.967	1.587	1.390	1.266	1.161	1.098	1.017
0	2.482	1.967	1.587	1.390	1.266	1.161	1.098	1.017
40	2.482	1.967	1.587	1.390	1.266	1.161	1.098	1.017
62	2.482	1.967	1.587	1.390	1.266	1.161	1.098	1.017
84	2.482	1.967	1.587	1.390	1.266	1.161	1.098	1.017

ms	5.0	6.0	7.0	8.0	9.0	10.1	12.1	14.1
250	4.132	3.464	2.928	2.482	2.120	1.808	1.379	1.092
300	4.132	3.464	2.928	2.482	2.120	1.808	1.379	1.092
400	4.132	3.464	2.928	2.482	2.120	1.808	1.379	1.092
500	4.132	3.464	2.928	2.482	2.120	1.808	1.379	1.092
550	4.132	3.464	2.928	2.482	2.120	1.808	1.379	1.092

Once you understand the concept of rail delta pressure, you should be comfortable with making these changes as needed. The key is to recognize what the ECU THINKS the delta pressure is, and what your actual delta pressure is in reality. Then you just have to make sure that where the ECU is going to look up injector values, it is going to be forced to pick something that matches the reality of how the car is built. This will save plenty of headaches later when trying to dial in fueling at idle or under boosted conditions.

For more information and the world's best EFI training, brought to you by an experienced OEM calibration engineer, check out our streaming videos at https://cartrainingonline.com/ or follow us on Facebook at Calibrated Success