Here is a brief discussion of turbo sizing for a 2.0 liter engine, for example, the 3-SGTE found in the 91-95 Toyota MR2 Turbo. This discussion will compare some compressor maps from the two main suppliers of turbos typically used on the MR2, Mitsubishi and Garrett. The Garrett maps discussed will be both the T series and the newer GT series maps. Some of the following discussion could be incorrect. If you have better information, share it with me and I will make some changes and we can both learn!

Before any calculations can be made or applied to the various compressor maps I have compiled, some assumptions about *volumetric efficiency* are needed. In general, normally aspirated cars have a *volumetric efficiency* of slightly less than 1 while turbo charged cars usually have a VE slightly above 1. So what is VE?

$$\frac{\text{Actual CFM}}{\text{Theoretical CFM}} = \text{VE}$$

In order to calculate the Actual CFM, your cars computer uses a series of sensors measuring either manifold air temp and pressure, or a mass air flow meter, or a combination of these tools (the MR2T uses MAF and manifold air temp I believe). Many things can effect the VE of your car and it is extremely important that the control system used by your ECU has the proper correction tables included to make changes when required. For example, below is a chart of the effect of altitude on the VE of your car:

Altitude (feet)	Atmospheric Pressure (psi)	Relative VE
0	14.7	1.0
1000	14.2	.965
2000	13.7	.931
3000	13.2	.892
4000	12.7	.865
5000	12.2	.833
6000	11.7	.803
8000	10.7	.742
10000	8.7	.681
12000	6.7	.645

Now, this is not the only factor that can influence your cars VE. What we are really after in a system like this is understanding the mass-flow rate of the air into combustion chamber. However that discussion will have to wait for another information article. But, other things, especially throttle position and air temperature have a direct effect on the VE of your engine. For example, a more efficient intercooler will have a larger pressure drop across it and will increase the VE.

For the sake of this turbo mapping exercise, I am going to make an assumption. Lets assume a VE of .90 for this purpose. For a four valve engine, numbers from .80 to .95 are generally accepted to be correct. If you live at high altitudes, or in the middle of the desert (like I do, drier air is actually better when compressed then moist air…cool dry air is ideal!), then you might want to use a different number. But, the purpose of this is to teach you how to use a compressor map. So onward we go.

So, next we need to create a table of various engine flow rates for our 2.0 liter (122 cubic inches or better yet, .0706 cubic feet). Here is the basic calculation required. The table is for a 2.0, you will need to re-do it if you have a stroker or some other engine.

Engine Flow (CFM) =
(engine displacement (in^3)) x (VE) x (engine speed (rpm/2)) x (manifold pressure ratio)

engine speed is RPM / 2 because it is a 4 stroke engine an only moves in air every other revolution

manifold pressure ratio is the pressure above atmospheric (boost level plus atmospheric) over atmospheric pressure I.E. 19.7/14.7 for 5 psi of boost. I am going to switch to units of bar for pressure now because that is what the compressor maps all use. Remember, 1 bar is atmospheric pressure and 2 bar is twice that or about 14.7 psi of boost.

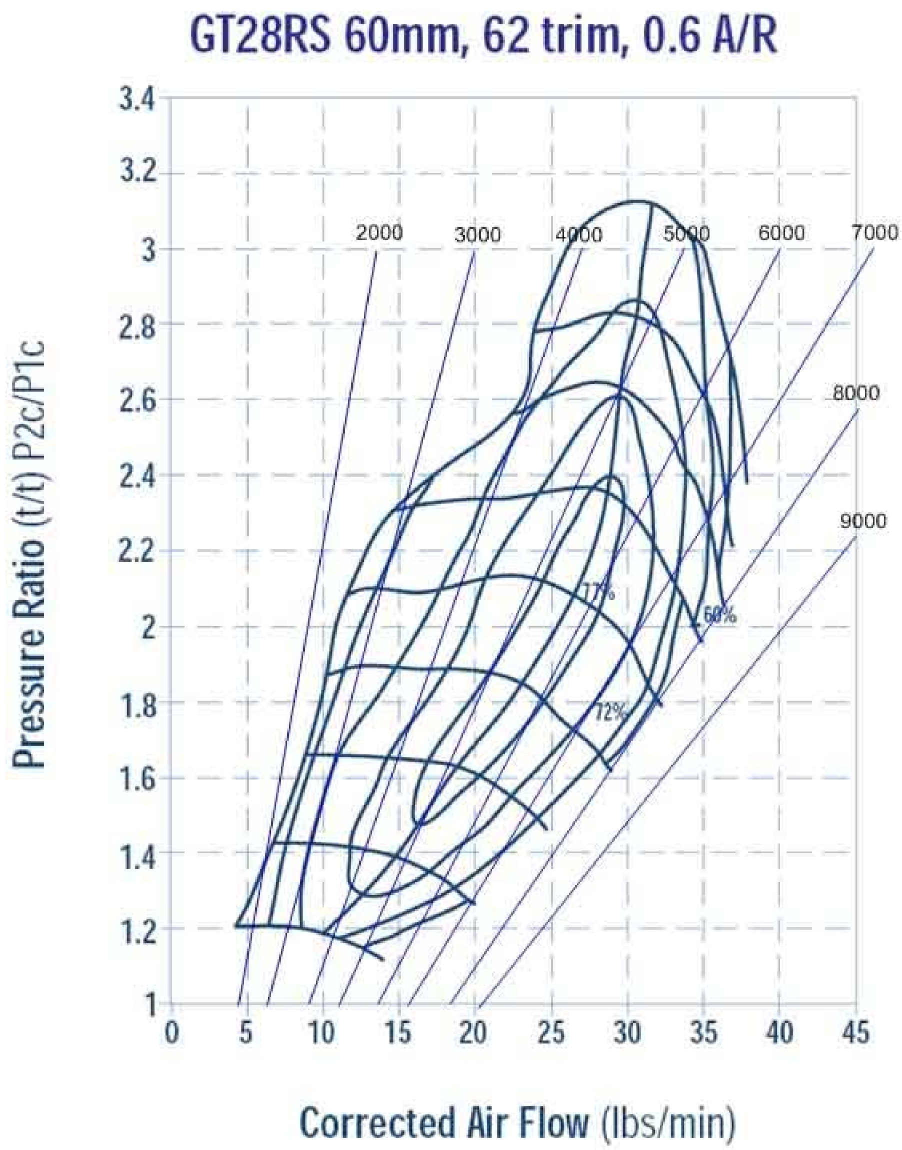
Here is the table for a 2.0 liter engine in CFM:

RPM	2000	3000	4000	5000	6000	7000	8000	9000
Boost								
3	190.7	286.0	381.4	476.7	572.1	667.4	762.8	858.1
2.8	178.0	267.0	356.0	445.0	534.0	623.0	711.9	800.9
2.6	165.3	247.9	330.5	413.2	495.8	578.5	661.1	743.7
2.4	152.6	228.8	305.1	381.4	457.7	534.0	610.2	686.5
2.2	139.8	209.8	279.7	349.6	419.5	489.5	559.4	629.3
2	127.1	190.7	254.3	317.8	381.4	445.0	508.5	572.1
1.8	114.4	171.6	228.8	286.0	343.3	400.5	457.7	514.9
1.6	101.7	152.6	203.4	254.3	305.1	356.0	406.8	457.7
1.4	89.0	133.5	178.0	222.5	267.0	311.5	356.0	400.5
1.2	76.3	114.4	152.6	190.7	228.8	267.0	305.1	343.3
1	63.6	95.3	127.1	158.9	190.7	222.5	254.3	286.0

Here is the same table converted to lbs/min

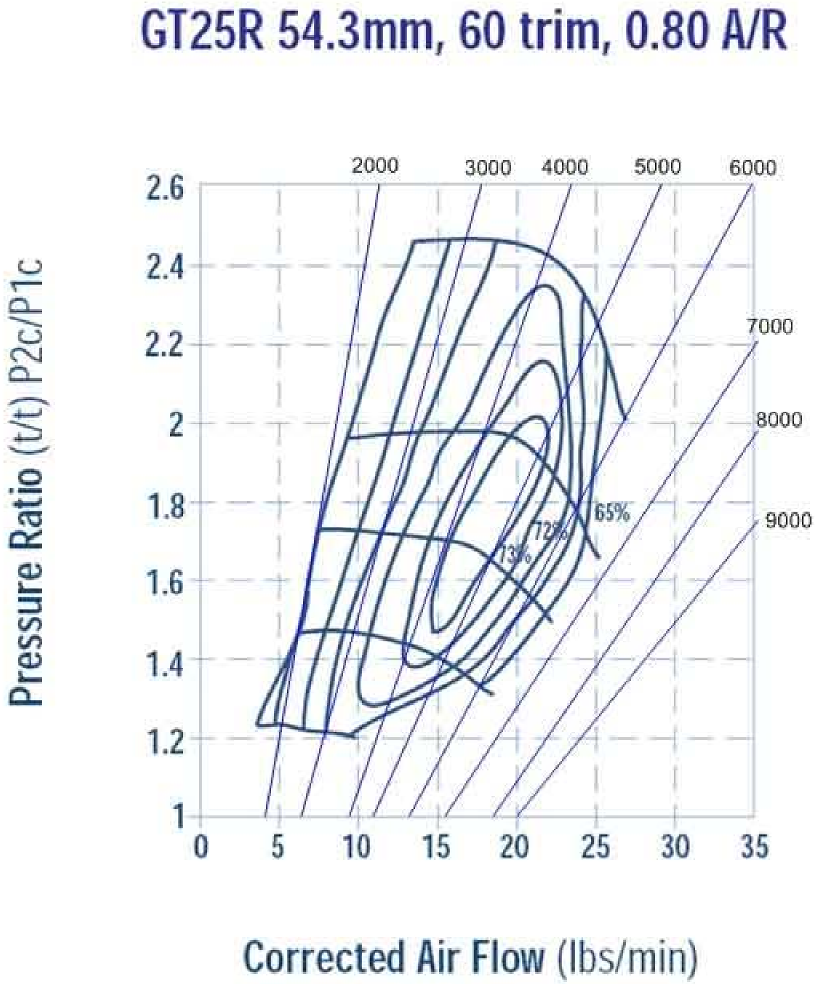
RPM	2000	3000	4000	5000	6000	7000	8000	9000
Boost								
3	13.3	20.0	26.7	33.4	40.0	46.7	53.4	60.1
2.8	12.5	18.7	24.9	31.1	37.4	43.6	49.8	56.1
2.6	11.6	17.4	23.1	28.9	34.7	40.5	46.3	52.1
2.4	10.7	16.0	21.4	26.7	32.0	37.4	42.7	48.1
2.2	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.1
2	8.9	13.3	17.8	22.2	26.7	31.1	35.6	40.0
1.8	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0
1.6	7.1	10.7	14.2	17.8	21.4	24.9	28.5	32.0
1.4	6.2	9.3	12.5	15.6	18.7	21.8	24.9	28.0
1.2	5.3	8.0	10.7	13.3	16.0	18.7	21.4	24.0
1	4.4	6.7	8.9	11.1	13.3	15.6	17.8	20.0

Okay, now that we have some flow numbers for our 2.0 liter 4 valve engine, it is time to fit some curves using the above data to some compressor maps for the popular turbo kits for this engine. So, how does a compressor map work? For starters, it is a plot of Air Flow versus Pressure Ratio. For a given Air Flow and Pressure ratio (boost level), a compressor efficiency level can be determined. Remember, it is extremely important to stay "in the chart" on the compressor map which means to the right of the left most line called the Surge Line. If the compressor surges, the compressor wheel can be damaged, and in some cases destroyed possibly slinging metal shards into your engine! Lets start with what looks to me to be a very good turbo for a stock engine spinning to around 7500 rpms with stock cams, the GT29RS – Disco Potato. As you can see below, my Photoshop skills are not perfect.

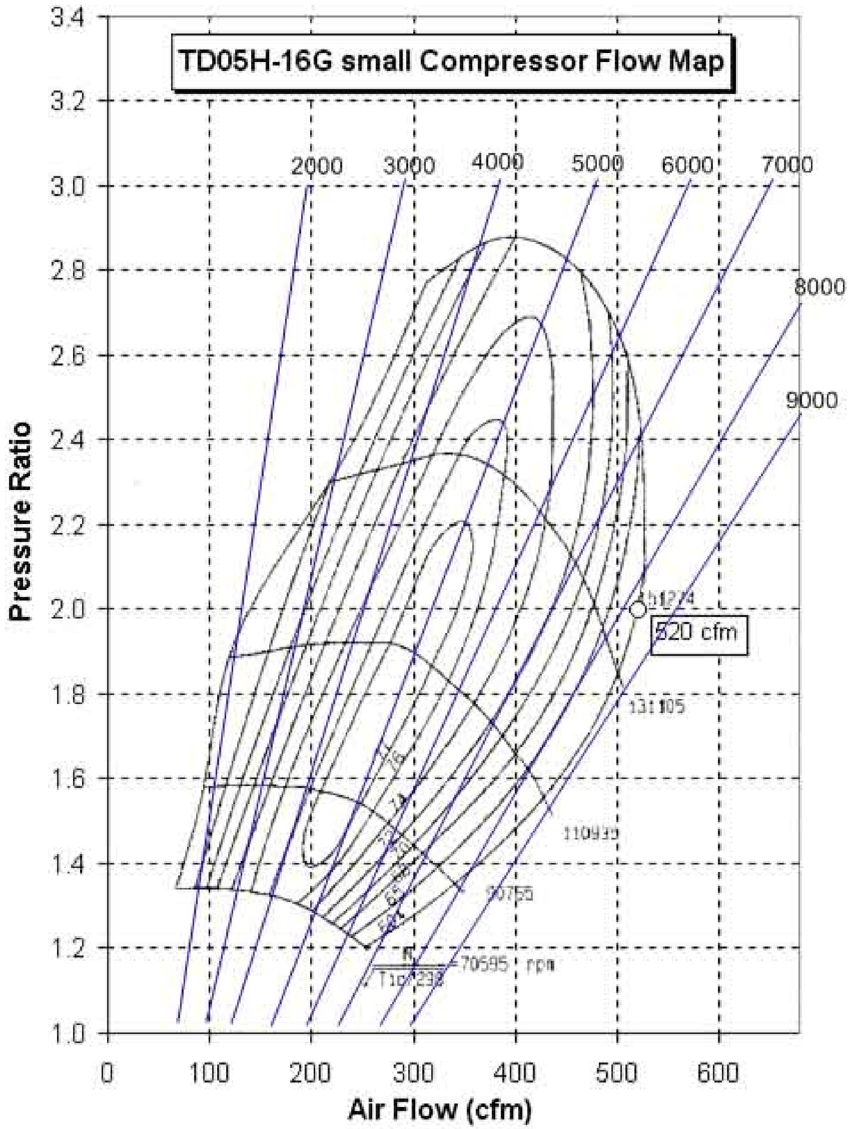


Each of the bluish lines I have drawn on each map represent engine rpm as taken from the above charts. This is really where the rubber meets the road for compressor maps. As you can see, this turbo has the ability to make approximately 15psi (2 bar) of boost as low as 2500 rpm. It starts be fairly efficient (over 70%) by 3000k, and can stay into the 70% range to our theoretical redline of 7500k. Pretty slick, but how does it compare to some of the other "popular" kitted turbos for this application? Lets start small and work towards bigger.

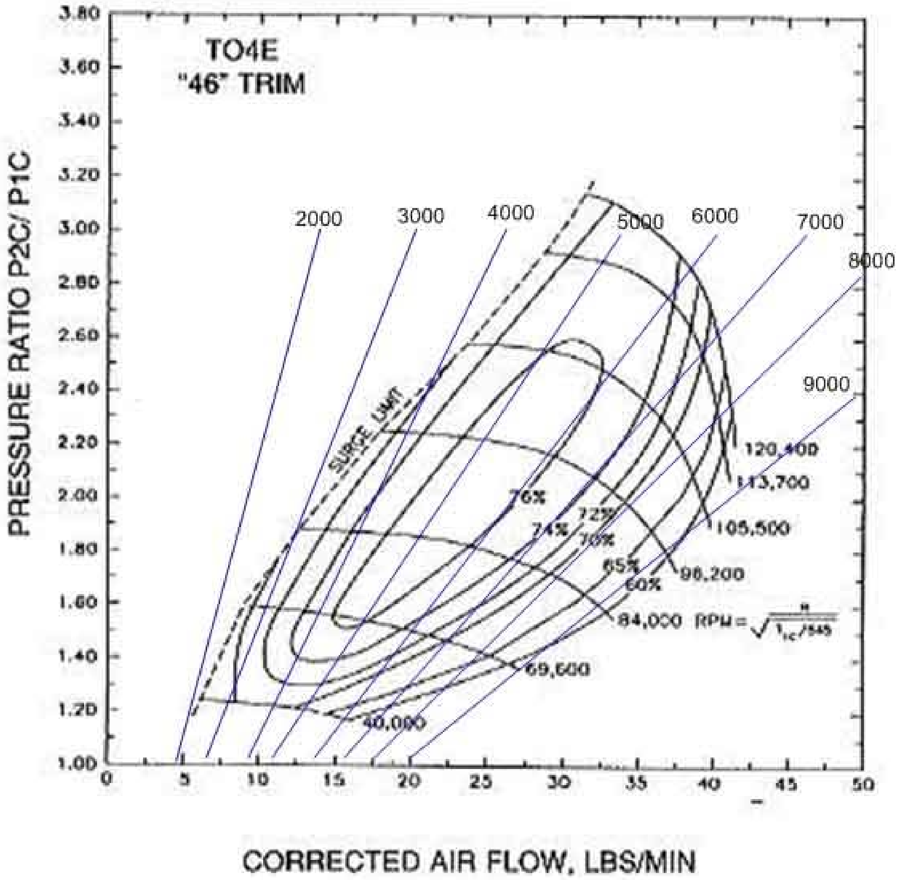
The GT25R looks to me to be too small for a 2.0 liter engine looking to run 15 psi. Above 6000k, the compressor is headed towards becoming a heat pump and at redline things are definitely not looking good. I imagine this turbo would perform only slightly better than a stock CT26 that came on MR2T's in the US.



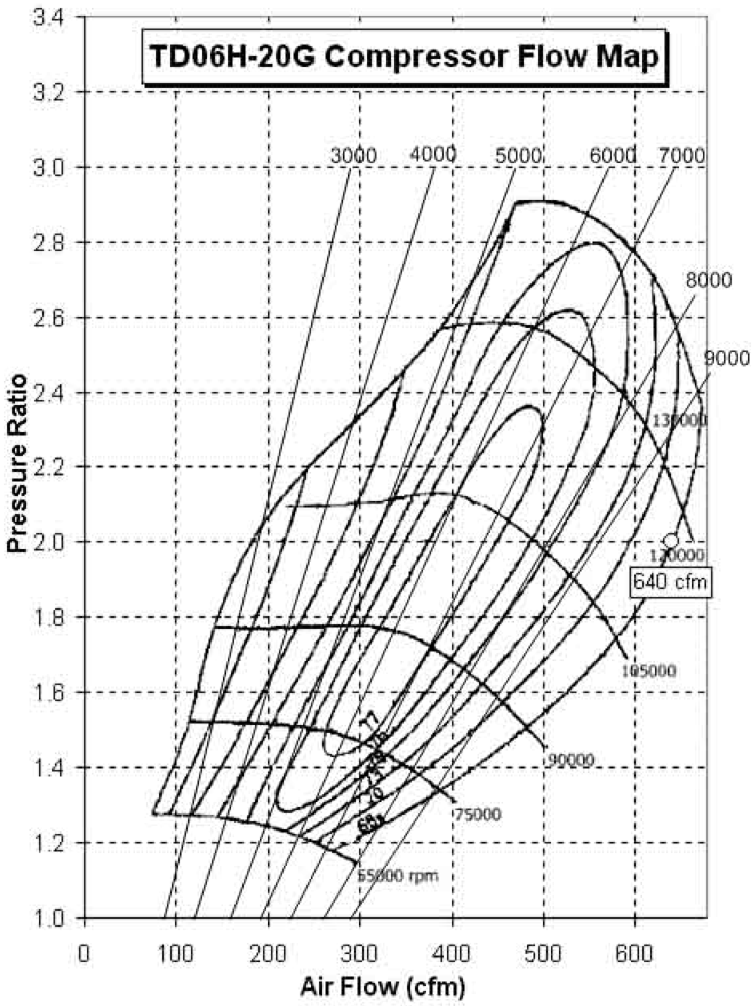
This example of at TD05-16G is actually quite surprising. For our example application, this turbo doesn't look too bad. Can make 15 psi at just over 2000k and is not completely choked at 7500k. However, this turbo does not have quite as much overall efficiency across the 15 psi range as the disco potatoes. That is not to say that this would not be an extremely nice "daily driven" turbo as well. With its reduced price compared to the ball bearing turbo series (GT series) from Garrett, it is pretty nice fit.



TD05H-16G small Compressor Flow Map
Pressure Ratio
Air Flow (cfm)
2000
3000
4000
5000
6000
7000
8000
9000
520 cfm
131105
110935
90755
70595 rpm
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0
100
200
300
400
500
600



The T04E 46 trim compressor from Garrett's older line of turbos is another popular kit turbo available for the 2.0 MR2T. At 15psi, this turbo also looks pretty nice. It can flow a bit more air than the previous TD05-16G, but at the expense of waiting just a bit for some spool up to happen. Unfortunately, the surge line on this turbo is a bit too "flat" to be perfect. That is not to say that this turbo is not breathing even better at around 7500k. This might be a good turbo for an MR2T used as a second car or for a daily driver who is willing to shift just a bit more. The benefit would be a bit better top end efficiency.



Here is the much talked about TD06-20G. This is a turbo that is getting to be a little big for our application. While the map does flex in a happy way towards the surge line, it is not very efficient at all below 4000k and will most likely not run well at rpm's below this line. If the owner of our car had some larger plans for the future including more revs or maybe some cams and bigger valves / intake track, this might be a good option. However, as a daily driver, this thing would require some serious shifting to make boost.

What would I choose if money was no limit and I wanted a good street car? The Disco Potato would be my choice. Otherwise, with a bit of a tighter budget, I would have trouble deciding between the TD05-16G and the T04E-46. I imagine both would run well with the TD05-16G spooling nearly like a stock turbo and the T04E-46 requiring just a bit of patience with a bit of a top end gain.

One thing I have not discussed is the idea's surrounding the turbine side of the turbo. From what I have been able to read and from my own experience, the best way to figure out what size turbine to use if options are available for your car are to do some experimentation. If the compressor is sized properly for your car, and most of these discussed so far would work well for our example (excluding the GT25R), I would recommend starting with the smallest turbine housing available with a high flow wheel. This will allow for housing changes to be made in the future without too much additional cost. For example, a T3 / T04E -46 hybrid should start with a big turbine wheel (a stage 3 or 5) and small housing (.48A/R). If you feel the car is choked at high rpms, the go to a larger housing. I bet you won't notice the marginal increase in top end, but you will miss the quick spool up of the smaller housing.

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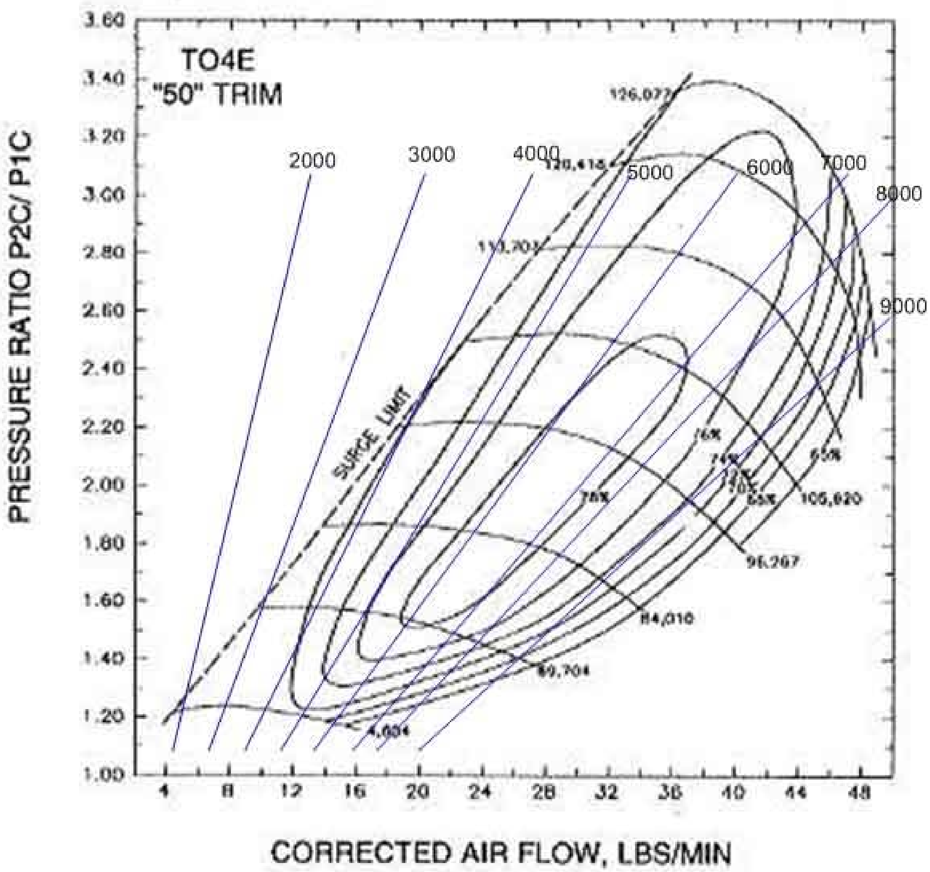
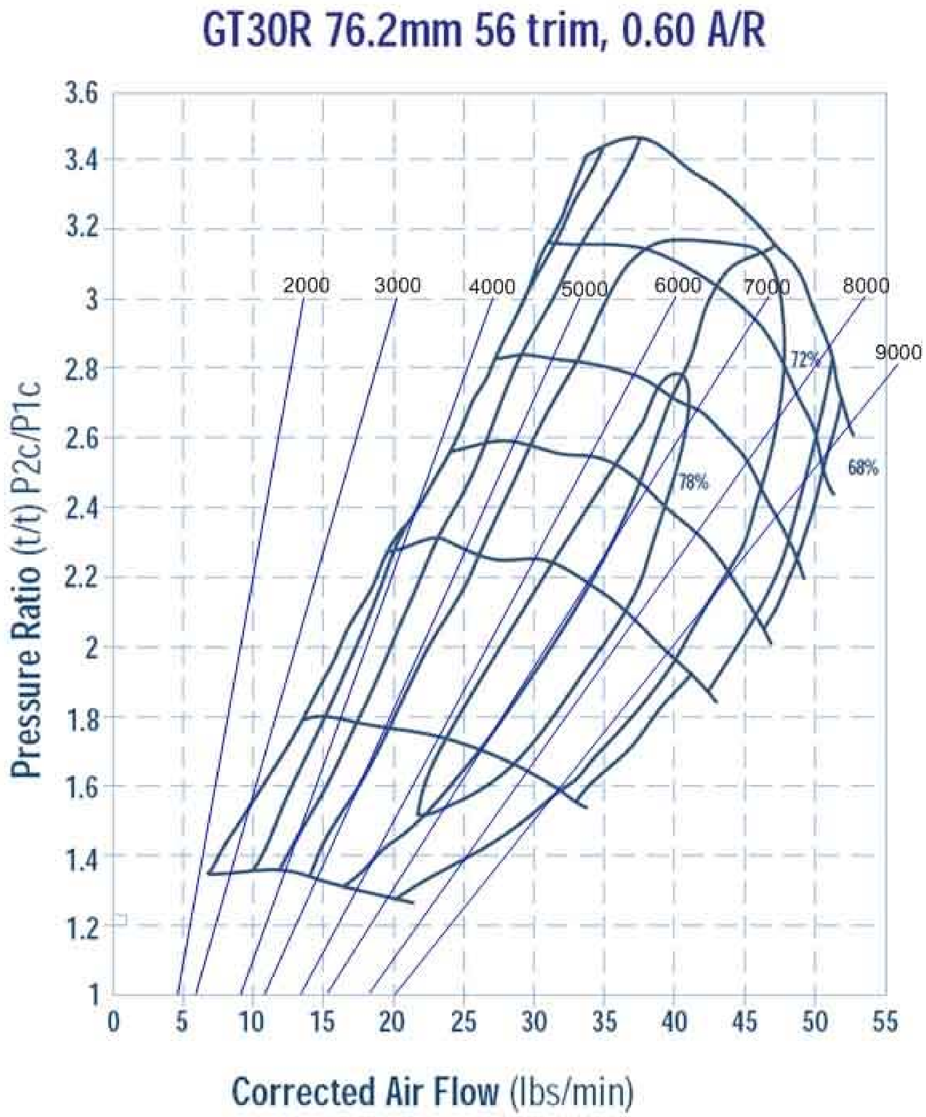
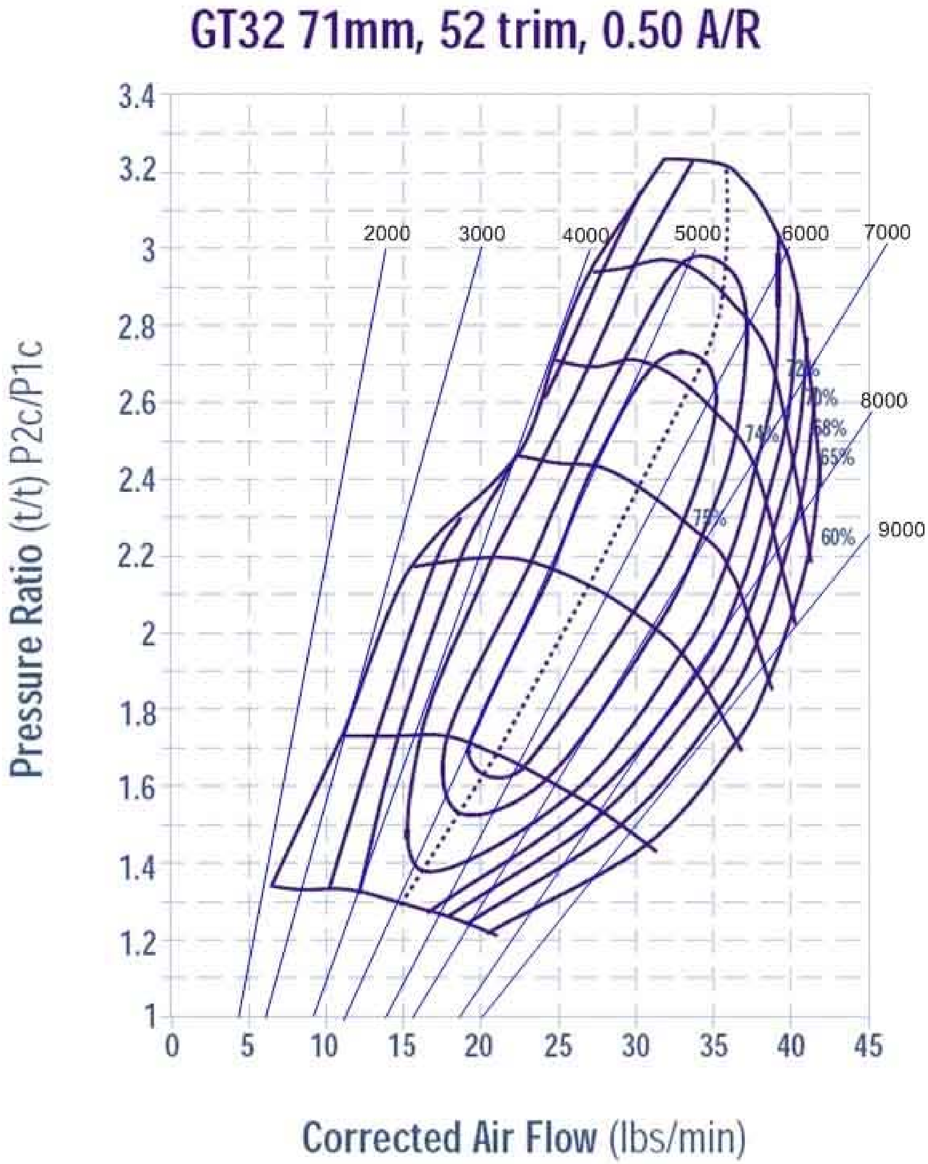
Now to discuss some of the other larger turbos that folks are running. I am going to present this information with a "grain of salt" if you will.

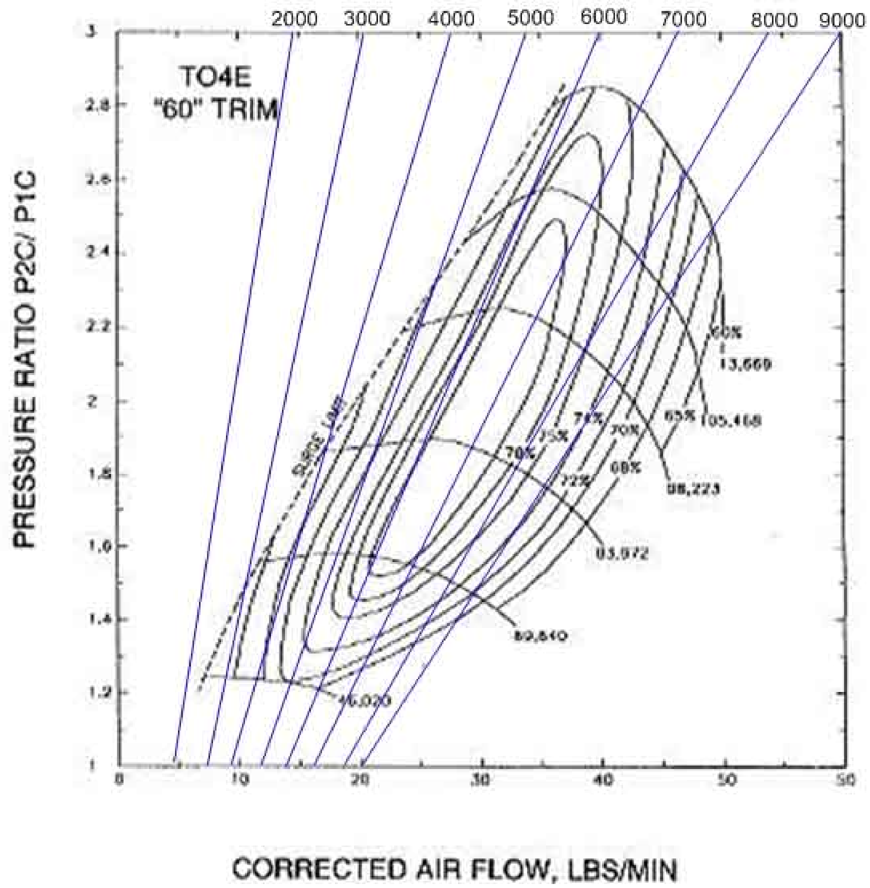


The T04E 50 trim has been used successfully to make over 400 hp at the crank at around 20 psi on various MR2T's. This plot shows that this turbo, while a bit larger, will be very happy in the rpm's surrounding redline, assuming a stock level near 7500 is being utilized.


GT30R 76.2mm 56 trim, 0.60 A/R
Pressure Ratio (t/t) P2c/P1c
Corrected Air Flow (lbs/min)
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0
5
10
15
20
25
30
35
40
45
50
55
2000
3000
4000
5000
6000
7000
8000
9000
72%
78%
68%

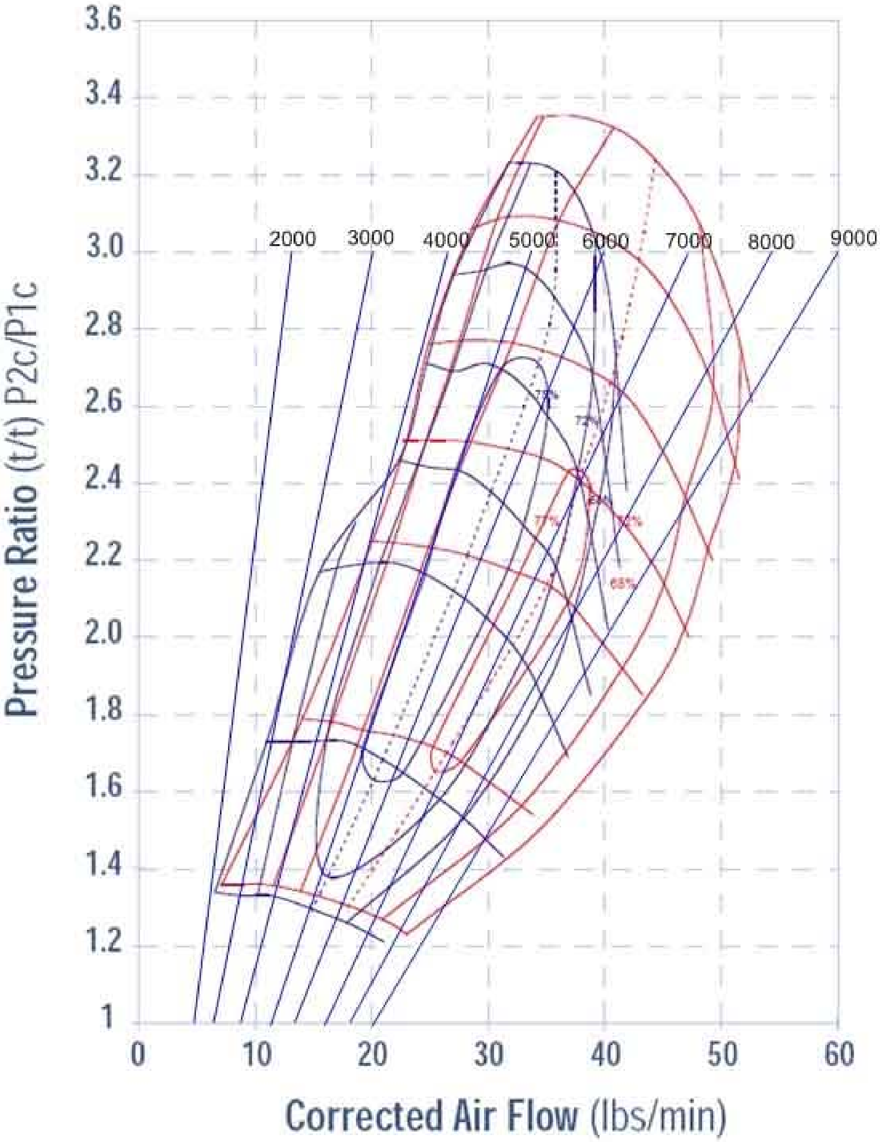


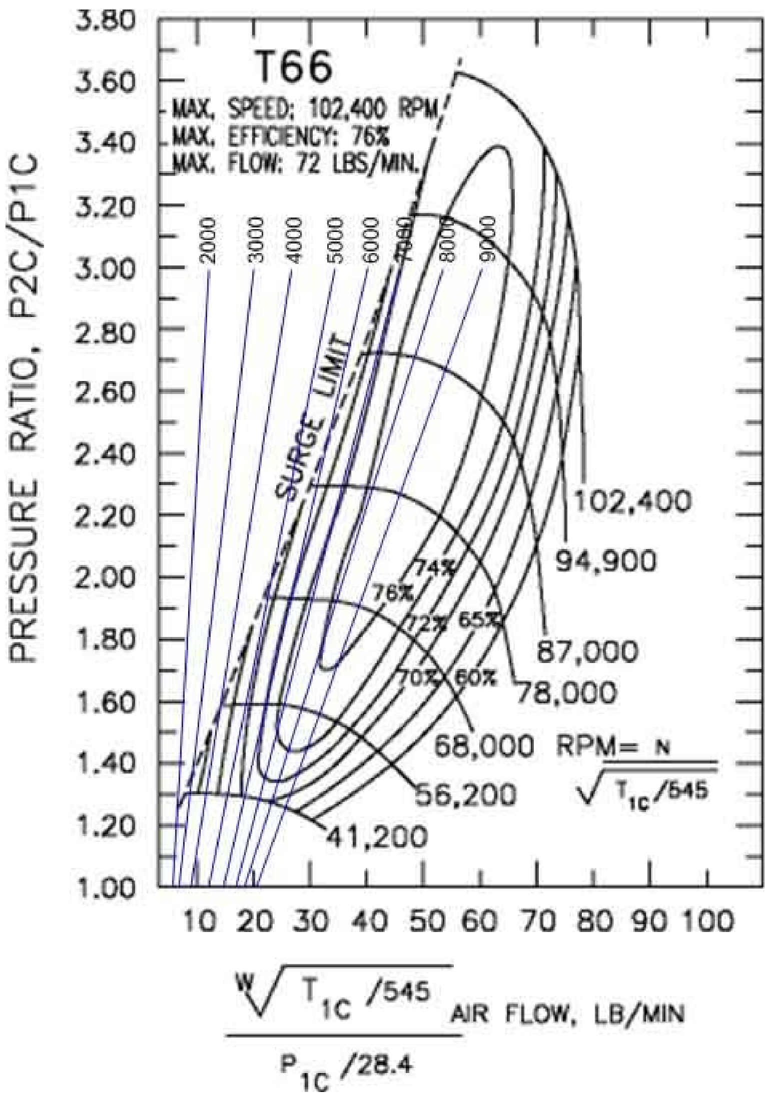
As the revs start to climb to a redline around 8000 or 9000, the GT 30 and the GT32 start to wake up and look pretty sweet. The will still be making some fairly efficient boost around 4500 rpm and can swing 9000k if you are careful and have the right mods and so on.



If you are on a budget, at T04E – 60 will actually move a similar amount of air when compared to a GT30 / GT32. However, more lower rpm performance will be abandoned again. If you decide to go this route, go for a larger turbine section like a .63 with a stage 3 or 5 wheel to take advantage of the high rpms.

GT35 71mm, 52 trim, 0.50 A/R
GT35 76mm, 52 trim, 0.50 A/R





The GT35 and T66 are definitely not for the weak at heart. These turbos will require monster rpms and a lot of prayers to get them running right. If you go this route, you better have a race car in mind because driving daily is going be a pain not to mention scary when 600 hp hits you and that bus in front of you isn't so far away anymore…..

In conclusion, I hope this article has helped you to better understand how to use a compressor map. Writing it has taught me a lot and forced me to buy books . . . If you have anything I can add or found something wrong, drop me a line. Look for more articles in the near future on how to size an intercooler and how to calculate the expected horsepower from a turbo charged engine!