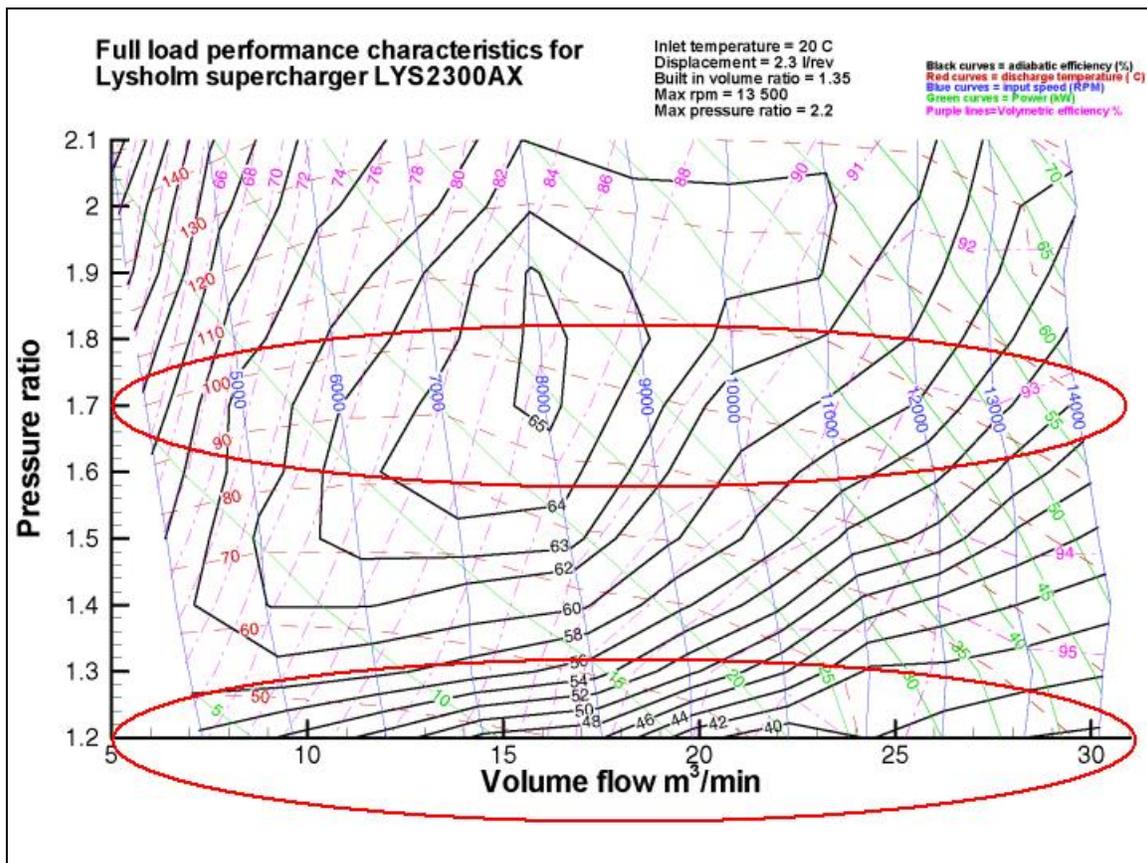


Interpreting Compressor Maps

I've provided this document for those who want to know how to correctly interpret and use a compressor map. By this, I mean to understand, in precise terms, what you see there with respect to the broadest range of applications. To minimize the possibility of any doubt about the veracity of this information, I have provided reference links.

Let's look at a typical map for a positive displacement blower. Below is the completely specified compressor map for a twin-screw compressor.



The vertical scale at the left of the map indicates the compressor's pressure ratio. Please note that the numbers along this scale are UNITLESS numbers. "Pressure Ratio" is just what the name implies. It's the ratio of the compressor's OUTLET pressure to its INLET pressure (or PRESSURE OUT / PRESSURE IN).

Neither on the above map nor on any other legitimate compressor map will you find any reference to psi or any other unit of measure for pressure. No pressure units of measure ever appear on compressor maps because compressors, especially turbochargers, are widely used in aviation, and, as we all (hopefully)

already know, atmospheric pressure varies considerably with altitude. (But the pressure ratio remains the same.) Since a compressor map, in order to apply equally to the widest range of applications, DOES NOT use pressure units, any generalization to the effect that a compressor's peak efficiency occurs at ANY specific psi is erroneous.

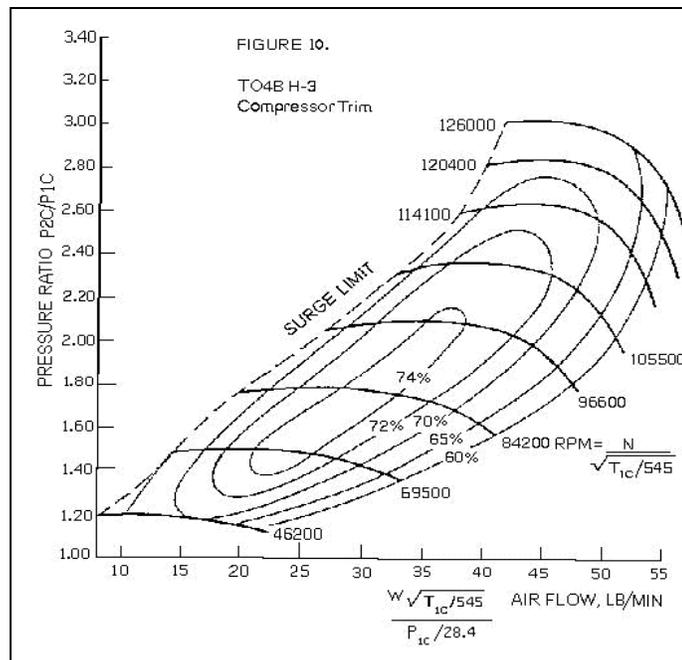
The scale along the horizontal axis of any compressor map (circled in red above) indicates the airflow volume through the compressor. The flow volume in the above map is expressed in cubic meters, because it was produced in Europe and Europeans use the metric system, but the values can easily be converted to cfm (cubic feet per minute) by applying a simple conversion factor. We Americans typically express compressor flow as cfm.

You will occasionally see compressor maps from some turbo manufacturers, such as *Turbonetics*, that express flow in pounds per minute (lb/min). Using pounds per minute to express compressor airflow is not standard, and, strictly speaking, is incorrect. The reason it's erroneous is that air becomes less dense as altitude increases, so although the volume of air (number of cubic feet or cubic meters) flowing through the compressor does not change with altitude, the WEIGHT of the airflow DOES CHANGE.

“The standard industry practice is to put this part of the graph in actual volumetric flow (such as ACFM) since the compression is constant for a given volumetric flow and compressor speed, NOT for a given mass flow.”

Reference: <http://www.gnttype.org/techarea/turbo/turboflow.html>

The web page referenced above contains a *Turbonetics* compressor map, which is reproduced here for convenience. The map contains only RPM and adiabatic efficiency curves for the compressor's operating envelope, limiting the map's utility, but it is still useful with regard to considering the compressor's surge limit. As you can see, the surge limit curve falls along the LEFT side of the compressor's operating envelope, not the right. This means, obviously, that surging becomes a problem at flow rates BELOW the intended operating envelope, NOT ABOVE it. In other words, surging rears its ugly head when trying to flow LESS air than the compressor was designed for, NOT MORE, i.e. when trying to use a compressor that is TOO LARGE for a particular application.



“To the left of the envelope, where it is marked "**surge limit**" the flow through the compressor is unstable and will go up and down and backwards unpredictably. This is surging. Do not pick a turbo that will operate in this area! It can be very damaging.”

Reference: *ibid*

Using compressor maps to select the right compressor:

One of the primary uses of compressor maps is to assist in selecting the best compressor for a particular application. How would we typically use the compressor map to estimate the optimum size for a specific application? *Turbonetics* recommends the following rule of thumb:

“The *Turbonetics* catalog says to pick a turbo that is close to the peak turbo efficiency at the engine's torque peak while still maintaining at least 60% efficiency at the maximum rpm of the engine.”

Reference: *ibid*

Obviously, the airflow through a compressor is directly related to its RPM. Furthermore, every compressor has a useable RPM range that is fixed, which is why you will see RPM curves on a compressor map. In addition to the flow scale, I have circled the RPM indications on the map above. Note that, since RPM and flow are directly related, they both increase along the same horizontal axis. However, the RPM curve may be considerably less linear for some compressors, because of design differences.

Calculating the airflow through the engine at different RPM:

$$(CID \times \text{PRESSURE RATIO} \times \text{RPM}) \div 3456 = \text{CFM}$$