Product Note, PN 454
Interpreting Flow Curves

January 9, 2023

Background

Flow curves are a commonly used tool to determine and compare pressure regulator performance. At first glance, flow curves from different pressure regulator (regulator) manufacturers all appear to be the same. The horizontal (X) axis is typically for flow and the vertical (Y) axis is for outlet pressure with inlet pressure and gas type noted. Unfortunately, there are subtleties between flow curves which can make a direct comparison a challenge or lead to false conclusions.

Pressure Measurement Device Location

Years ago, pressure gauges were always installed on the pressure regulator itself. Today, in the semiconductor and other clean industries, low pressure measurement devices are typically installed downstream of the regulator rather than on a port of the regulator itself for a variety of reasons. The location of the pressure measurement makes a difference in the pressure drop observed with increasing flow. The outlet port and fittings are a flow restriction which contribute to droop (pressure drop with increasing flow). Monitoring pressure on the regulator at a low pressure port will have less pressure drop than monitoring pressure downstream of the regulator because it is upstream of the outlet port. Manufacturers can use either location during pressure drop testing to monitor pressure which complicates flow curve comparison between manufacturers.

Initial Droop

The initial pressure drop (droop) when flow begins through a regulator can be difficult to properly depict on a curve due to the flow curve graduation granularity. Some manufacturers show a small tail for the initial pressure drop as flow begins, some just start the curve at the outlet set point showing the total pressure drop as flow increases while others start the curve at zero flow at the adjusted set point less initial droop noting set point in the flow curve title. Pressure drop at desired flow is calculated by subtracting the pressure at flow from pressure at no flow. One needs to be careful to account for the initial droop. In the case of the curve starting at

no flow at a pressure lower than the set point, one must subtract from the stated set point, not the pressure at zero flow where the curve contacts the Y axis because it is depicting pressure after the initial pressure drop. Please refer to Appendix A, comparison 1 for an example.

Some manufacturers start the flow curve at a given flow, such as 200 sccm, noting such in a footnote. This does not show the initial pressure drop and can make comparison to other flow curves difficult because the set point at zero flow may not be stated. Please refer to Appendix A, comparison 2 for an example.

Lock up, which some refer to as creep, is the pressure rise above set point as flow drops to zero from a very low flow rate. Lock up is universally not included (ignored) with flow curves which only depict pressure drop from a set point.

Logarithmic Scale

Some manufacturers use a logarithmic scale for the X axis. This means the amount of flow per graduation increases moving away from zero flow. This enables one to see lower flow performance better. This also tends to make the pressure regulator performance appear deceptively better. The flow curve tends to show less pressure drop (flatter curve) for more of the curve with the drop compressed to fewer graduations. Please refer to Appendix A, comparison 3 for an example.

Outlet Fitting Size

The outlet fitting size can impact droop. As previously explained, the outlet port is a flow restriction that contributes to pressure drop. A larger fitting size can have a larger inside diameter (bore) which reduces the restriction. Larger bores intersecting reduce the pressure drop at this juncture which is typically 90°. Larger sized fittings without larger through bores will not help reduce this restriction. The converse, smaller fitting sizes than standard, can increase the pressure drop through the regulator depending upon the pressure measurement location and adversely affect the flow curve.

Flow curves are generally presented with the typical fitting size for a given model and fitting size may not be noted. If larger optional fittings are used for a flow curve, the fitting size should be noted on the curve.

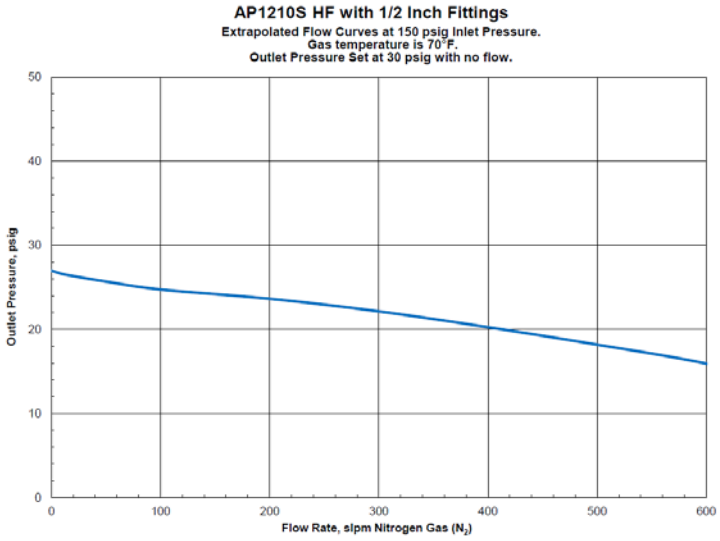
Conclusion

There is more to comparing flow curves than just verifying that the test gas, inlet pressure and outlet pressures are the same. One must look carefully at the flow curves to understand what is being presented. How the initial pressure drop with flow is shown, fitting size, pressure measurement location, etc. all impact the shape of the flow curve.

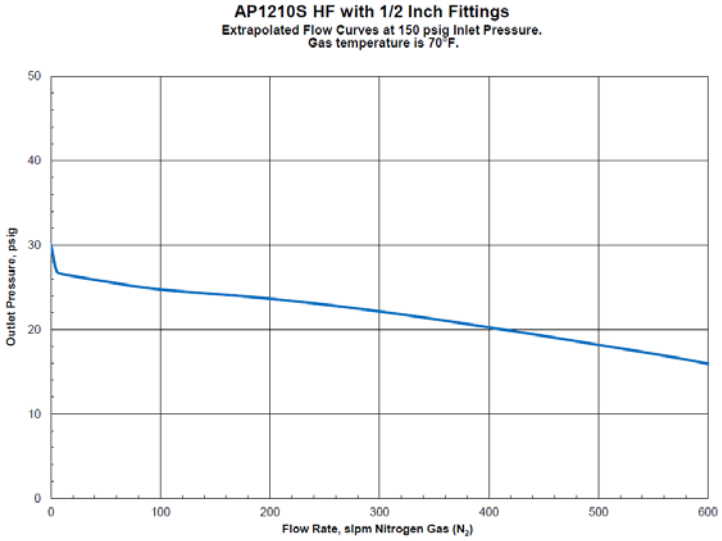
Appendix A, flow curve comparisons

1) Initial droop not shown

Initial droop not shown from 30 psig set point as curve appears to show a lower pressure set point.

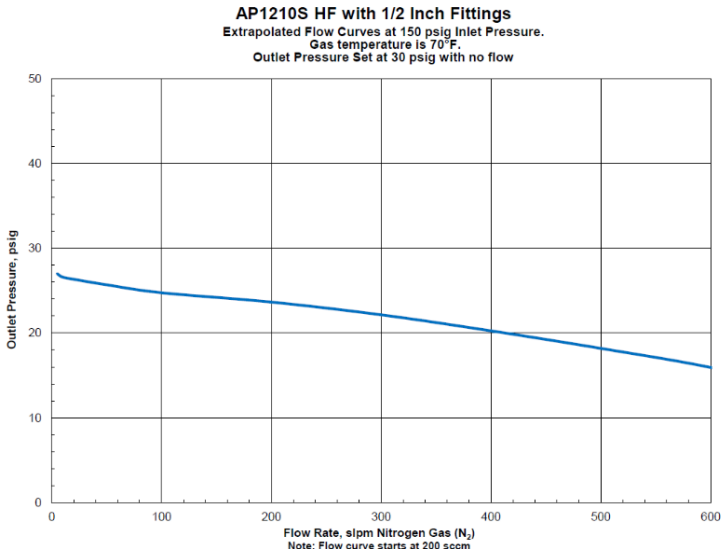


Same flow curve, initial droop shown as a tail

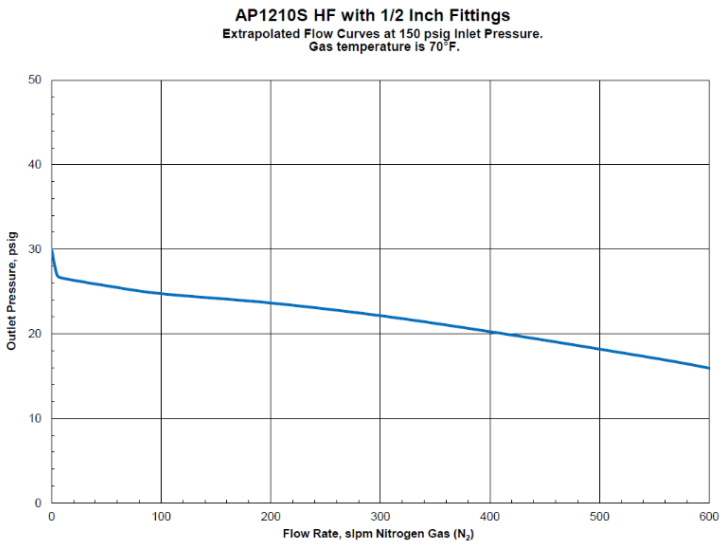


2) Curve does not start at zero flow

Flow curve starts from a low flow rather than 0 flow. This excludes initial droop and appears to have a lower set point than 30 psig.

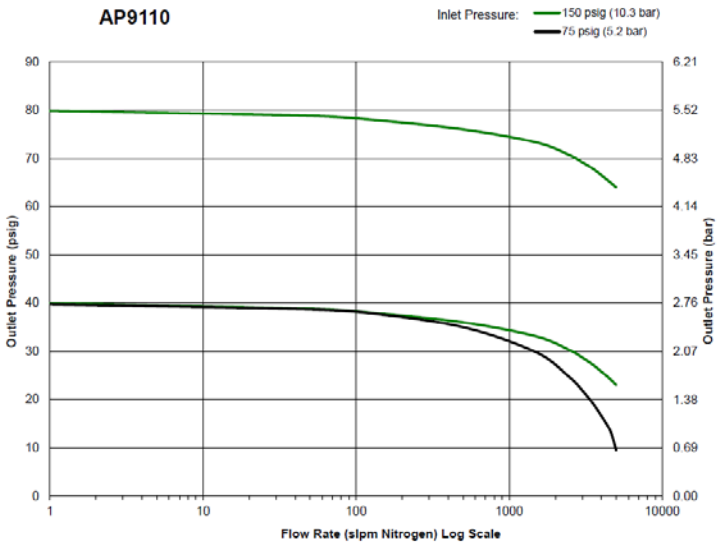


Same flow curve with flow starting at zero to show initial droop



3) Logarithmic scale

Logarithmic scale for flow (X axis)



Same flow curve with equal graduations for flow (X axis)