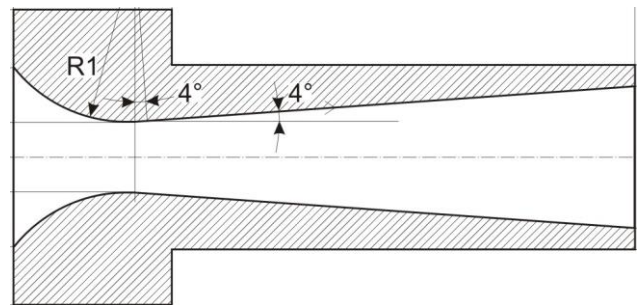


#### Operating Principle

The Sonic Nozzle (Critical Flow Nozzle, Critical Flow Venturi or Sonic Venturi) consists of a smooth rounded inlet section converging to a minimum throat area and then diverging along a pressure recovery section or exit cone. As a gas accelerates through the Nozzle, its velocity increases and its density decreases. The maximum velocity is achieved at the throat, the minimum area, where it reaches the desired speed of sound (Mach 1).

The Sonic Nozzle is operated by pressurizing the inlet (P1) or evacuating the exit (P3), to achieve an Inlet/Outlet (P1/P3) pressure ratio of 1.4 to 1 or greater. This ratio maintains the Nozzle in a "choked" or "sonic" state. In this state, only the upstream pressure (P1) and temperature are influencing the flowrate through the Nozzle. The flowrate through the Nozzle becomes nearly a linear function of the inlet pressure. Doubling the inlet pressure doubles the flowrate.



The simplest flow system would use an inlet pressure regulator to control air pressure and a thermocouple to measure temperature. Adjusting the pressure regulator will change and maintain the flow through the Nozzle.

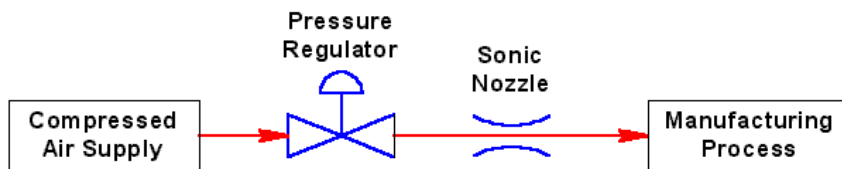
Pressure differences within a piping system travel at the speed of sound and generate flow. Downstream pressure disturbances cannot move upstream past the throat of the Nozzle because the throat velocity is higher and in the opposite direction. Since these pressure disturbances cannot move upstream past the throat, they cannot affect the velocity or the density of the flow through the Nozzle. This is what is referred to as a choked or sonic state of operation. This is one of the greatest advantages of Sonic Nozzles when compared to sub-sonic flowmeters (Venturis or Orifice Plates where any change in downstream pressure will affect the differential pressure across the flowmeter, which in turn, affects the flow).

As a result, Sonic Nozzles are ideal for applications where steady inlet flow is required even though there is pulsating or varying gas consumption downstream. They are also ideal as flow limiters since with a fixed upstream pressure both mass and volumetric flows are fixed.

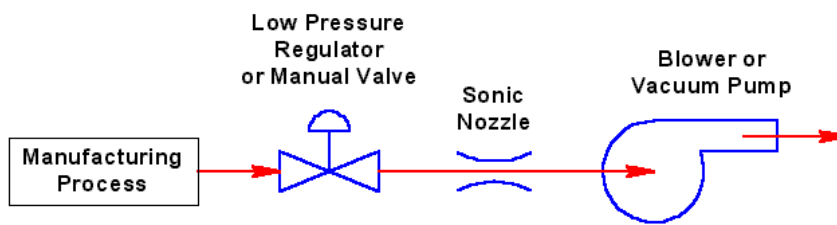
Accuracy levels of  $\pm 0.25\%$  of reading or better can routinely be achieved since there are no moving parts.

## Typical Sonic Nozzle Installation Configurations

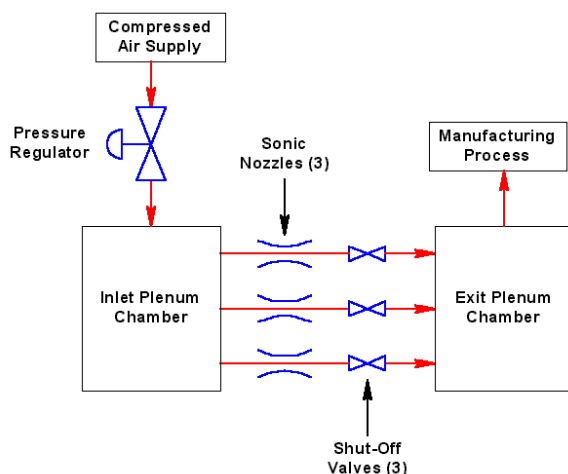
**Pressurized System** This is the most common installation arrangement. A pressurized gas source is used with a pressure regulator upstream of the Sonic Nozzle. The measured process downstream may be at atmospheric pressure or greater as long as a minimum of 1.4 pressure ratio is maintained across the Nozzle. In this arrangement, flow pulsations or fluctuations from the process downstream will not influence the flow through the Sonic Nozzle. The airflow range is only limited by the maximum pressure of the available air supply.



**Vacuum System** If the manufacturing process operates at or near atmospheric pressure, a pull-thru or vacuum system can be used to measure the airflow. This arrangement is good for maintaining airflow to a steady process, but flow range is limited because the upstream pressure of the nozzle is not variable.

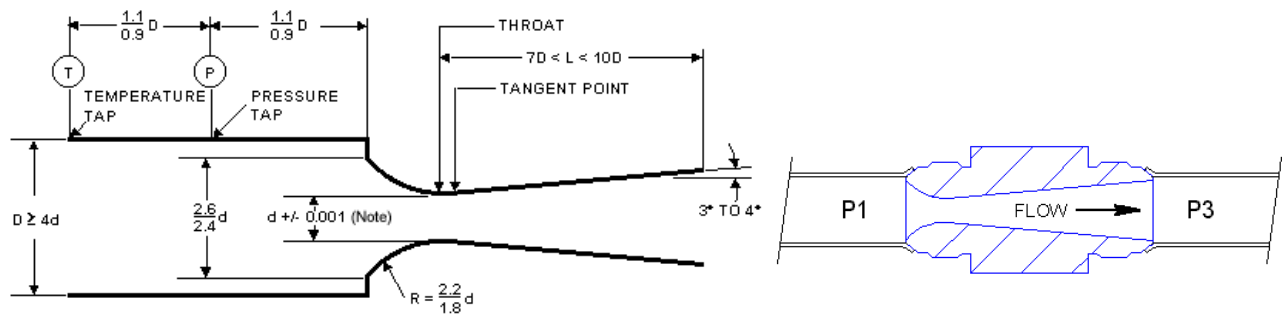


**Multiple Nozzle System** To extend the flow range beyond that of a single Nozzle, multiple Nozzles can be installed in parallel. In the arrangement shown in the schematic below, the three Nozzles can be operated individually, in pairs, or all three at once. This system allows the use of binary operation. Each Nozzle is sized to flow approximately twice that of the next smaller one. It's not exactly twice because a Sonic Nozzle cannot be reduced to zero flow, there is a minimum flow necessary to keep the Nozzle choked. For example, if these three are sized for 1, 2, and 4 nl/min, the total covered flow range will be 0.2 to 7 nl/min. For example, 2 nl/min would be obtained by opening Nozzle #2. 5 nl/min would be obtained by opening Nozzles #1 and #3. The flows in between are achieved by adjusting the pressure regulator. Although this is a simplified example, the application is valid and can be extended to any number of Nozzles and flow ranges as the photo of nozzle manifolds shows below.



TrigasDM offers Sonic Nozzles in accordance with ASME and ISO standards. The geometry is such that the gas is accelerated along the circular arc converging section and then is expanded in a conical diverging section, which is designed for pressure recovery. In the throat, or minimum area point of the Sonic Nozzle, the gas velocity becomes equal to the speed of sound. At this point, gas velocity and density are maximized, and the mass flow rate is a function of the inlet pressure, inlet temperature, and the type of gas.

$$M \propto \frac{P}{\sqrt{T}}$$



### ASME / ISO Torodial Throat Critical Flow Venturi

A complete metering system includes a Sonic Nozzle, Inlet and Exit Sections, Pressure and Temperature Sensors, and a Flow Computer.

### SONIC NOZZLE ADVANTAGES

- Internationally Recognized
- Mass Flow Varies Linearly with Inlet Pressure
- Minimal Upstream Piping Required
- Long Term Accuracy
- Excellent Repeatability
- No Moving Parts
- Differential Pressure Measurement Not Required
- Flow Rate Is Not Affected by Downstream Flow Disturbances
- Mass Flow is Constant with Varying Downstream Pressure

## TYPICAL SONIC NOZZLE APPLICATIONS

- Calibration of Gas Flow Meters
- Gas Flow Metering
- Calibration of Turbine Engine Component Gas Passages
- Calibration of Automotive Component Air Passages
- Measurement of Automotive Induction Air
- Automotive Emissions Testing
- Compressor Discharge Capacity Tests
- Valve CV Tests
- Flow Limiting
- Over Speed Protection of Gas Flow Meters

Flow Range: 10 – 20000 nlit/min or higher  
Depending on size of nozzle selected. Consult Factory.

Gases: Air and non-hazardous gases

Accuracy:  $\pm 0.25$  % Of Reading or better  
Depending on calibration and type of gas. Consult Factory.

Repeatability: As good as  $\pm 0.1$  % Of Reading, depending on Pressure Transducer and the application conditions.

Pressure Range: Up to 10 bar (higher pressures available)

Temp. Range: 10-50 °C