Total and Static Pressure

Understanding the Distinction Between Total, Static, and Dynamic Pressure

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When discussing a piping system, the term "pressure" is often used to describe a key fluid property that plays an important role in the operation of equipment like pumps, control valves, tanks and vessels, and other devices. But like many terms used in engineering, there are nuances in meaning that must be taken into account to avoid miscommunication, confusion, and costly mistakes. Quite often, key qualifiers that distinguish between "total pressure", "static pressure," and "dynamic pressure" are not used. But sometimes the distinction is important, just as the difference between "mass flow rate" and "volumetric flow rate" must be made to be concise when discussing "flow rate".

Definition and Units

The classical definition of pressure is the amount of force acting on a surface per unit area, as shown in Figure 1.

\[
\text{Pressure} = \frac{\text{Force}}{\text{Area}}
\]

This gives pressure the units of pounds per square inch (lb/in² or psi) or newtons per square meter (Pascal). Other units commonly used for pressure include the atmosphere, bar, kilopascal, torr, inches (or mm) of mercury, and inches (or mm) of water.

**Total Pressure**

The Total Pressure is the force per unit area that is felt when a flowing fluid is brought to rest and is usually measured with a pilot tube type instrument, shown in Figure 2. The Total Pressure is the sum of the Static Pressure and the Dynamic Pressure.

\[
P_{\text{total}} = P_{\text{static}} + P_{\text{dynamic}}
\]

Total pressure is often referred to as the Stagnation Pressure.

**Static Pressure**

Static Pressure is felt when the fluid is at rest or when the measurement is taken when traveling along with the fluid flow. It is the force exerted on a fluid particle from all directions and is typically measured with gauges and transmitters attached to the side of a pipe or tank wall. Because this is what most pressure gauges measure, static pressure is usually what is implied when just the term "pressure" is used in discussions.

**Dynamic Pressure**

The difference between the Total and Static Pressure is the Dynamic Pressure, which represents the kinetic energy of the flowing fluid. Dynamic pressure is a function of the fluid velocity and its density and can be calculated from:

\[
P_{\text{dynamic}} = \rho \frac{v^2}{2g}
\]

*The equation above is in US units, if calculating \( P_{\text{dynamic}} \) for Metric units (e.g. Pascals) the acceleration of gravity \((g)\) can be omitted.

**When to Make the Distinction**

Depending on the application, the difference between total and static pressure may be negligible, but for others, neglecting the difference may result in costly mistakes.

For many liquid applications, the pipelines are sized to ensure low fluid velocities to reduce the head loss and pressure drop for a given flow rate, resulting in a small value of dynamic pressure. Also, because of the accuracy and scale of the instrument used to measure the pressure, the distinction between total and static pressure may be neglected.
In Figure 3, the pipe size is changed to result in different fluid velocities for 700 gpm of water flow, resulting in different amounts of dynamic and static pressure for an inlet total pressure of 100 psig. For the Low Velocity case with a 6 inch pipe size, 700 gpm results in a velocity of about 7.8 ft/sec. Of the 100 psig total pressure, 99.59 psig is static pressure and 0.41 psi is dynamic pressure. If the pressure is measured on a 0-150 psig pressure gauge, the difference between the total and static pressures will most likely not be discernible. In the Moderate Velocity case with a 4 inch pipe, 700 gpm results in a fluid velocity of 17.6 ft/sec, a dynamic pressure of 2.1 psi, and static pressure of 97.9 psig. In the High Velocity case with a 3 inch pipe, the fluid flows at about 30 ft/sec. The dynamic pressure is about 8.2 psi, so of the 100 psig total pressure, 93.8 psig is static pressure. In a 2.5 inch pipe for the Extremely High Velocity scenario, the 47 ft/sec velocity results in 15 psi of dynamic pressure and 85 psig of static pressure.

For gas applications shown in Figure 4, the distinction between total and static pressure again will again depend on the amount of dynamic pressure, but because the density of a gas is much lower than that of a liquid, a much higher velocity is needed before the difference between total and static pressure needs to be made. Notice the various pipe sizes, fluid velocities, and static pressures for an inlet total pressure of 100 psig and a mass flow rate of 7500 lb/h of 350F steam with a density of 0.248 lb/ft³.

Figure 3. Difference between Total, Static, and Dynamic Pressure for various fluid velocities in liquid applications.

Figure 4. Difference between Total, Static, and Dynamic Pressure for various fluid velocities in gas applications.

Concise Use of Terminology

When evaluating the operating parameters of a piping system, the distinction between total and static fluid properties may or may not be important. For most liquid applications, fluid velocities are intentionally kept low to minimize the amount of head loss and power consumption of the system. This results in a small amount of dynamic fluid energy, making the difference between total and static pressures indiscernible on most industrial pressure gauges.