TECH TIP

Calculating Maximum Blocked in Discharge Pressure

"What is the maximum blocked in discharge pressure of the pump?" You have probably heard this question before if you have ever participated in a Process Hazard Analysis (PHA) / Hazard and Operability Study (HAZOP). The PHA facilitator normally looks to the engineer in the room to provide the answer whenever the PHA scenario arises in which the discharge path from a centrifugal pump is blocked (e.g. block valve is inadvertently closed on pump discharge, control valve fails/malfunctions closed on pump discharge, etc.).

Although the question is seemingly simple, oftentimes, there is confusion about what the term means and how to accurately calculate this for a given HAZOP scenario. In this Tech Tip, we will provide a simplified discussion of how to calculate maximum blocked in discharge pressure for a centrifugal pump.

Centrifugal Pumps vs. Positive Displacement Pumps

Maximum blocked in discharge pressure is different for centrifugal and positive displacement (PD) pumps.

Centrifugal pumps use a rotating impeller to impart energy to the fluid and this is what determines the maximum blocked in discharge pressure. The amount of liquid that passes through the pump is inversely proportional to the pressure at the pump discharge, as demonstrated by the centrifugal pump curve in **Figure 1**. The calculations in this Tech Tip do not apply to PD pumps, as the outlet flow of these pumps vary little with respect to the pressure at the pump discharge. This is because for PD pumps, their moving displacement mechanism pushes a slug of liquid out at a constant rate. Thus, when blocking in the discharge of a PD pump, the pressure is seen to rise infinitely until a point of failure is reached. This is why PD pumps are designed with a pressure relief valve on the discharge of the pump, while this is often not the case for centrifugal pumps. **Figure 1** displays the difference between a PD and centrifugal pump curve.

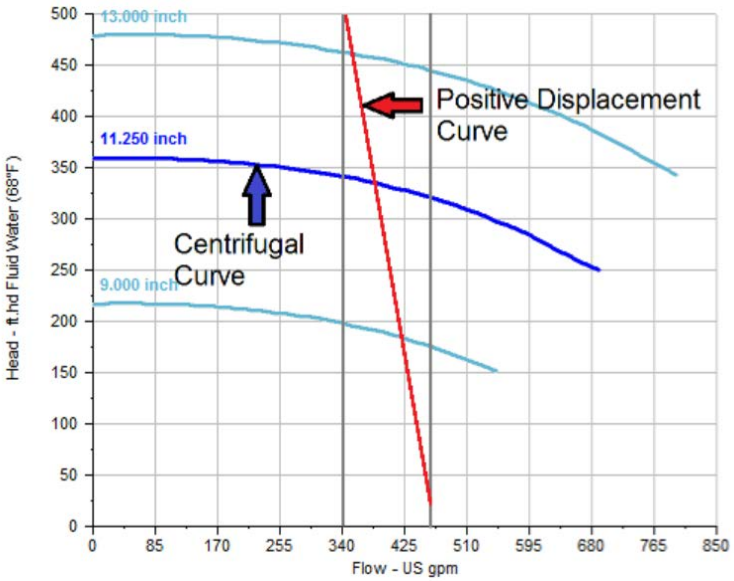

Figure 1: Centrifugal vs. Positive Displacement Pump Curves

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Steps for Calculating Maximum Blocked in Discharge Pressure

1. Refer to Pump Curve to find the Pump Deadhead Pressure

A pump curve is the plot of the outlet pressure as a function of flow. Pump curves can be obtained from your centrifugal pump's manufacturer. On a typical pump curve, flowrate (Q) is on the horizontal axis (x-axis), while head (H) (also referred to as total dynamic or differential head (TDH)) is on the vertical axis (y-axis).

To find the deadhead pressure of a pump, trace the pump curve back to the far left (where the flow approaches 0 gallons per minute (gpm)) and this point on the y-axis is the deadhead pressure. Typically, the y-axis is presented as head in units of feet (ft) instead of pressure in units of pounds per square inch gauge (psig) since pressure is dependent on the specific gravity of the fluid.

Figure 2 displays an example of a centrifugal pump curve and the different types of information that can be presented on these curves. For this pump curve, for an impeller size of 9.5", the deadhead pressure is seen to be 90 ft.

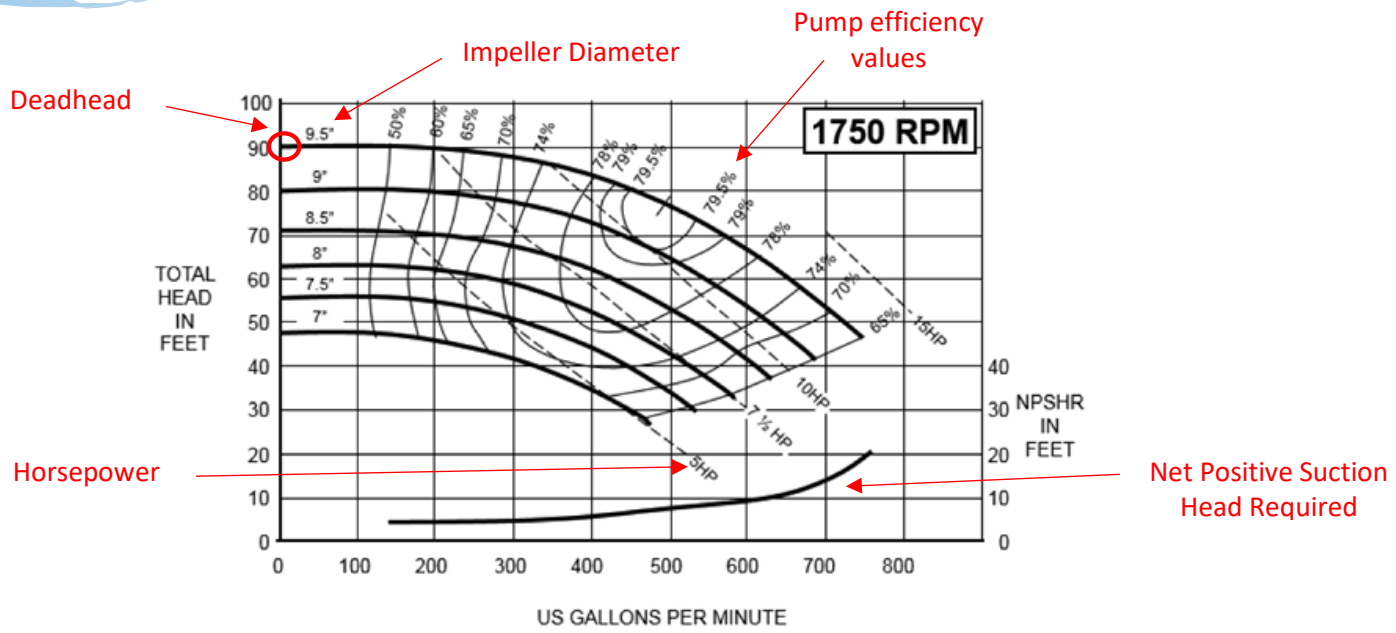

Figure 2: Centrifugal Pump Curve

2. Convert Deadhead Pressure from Feet of Head to Psig

The pressure in units of psig can be calculated using the following equation:

$$P = 0.433 \times H \times SG$$

Where:

$P = Pressure\ (psi\ /\ psig)$

$H = Head\ (feet)$

$SG = Specific\ Gravity\ (unitless)$

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3. Calculate Maximum Blocked in Discharge Pressure by adding Deadhead Pressure and Suction Pressure

The following equation provides the maximum blocked in discharge pressure of a centrifugal pump:

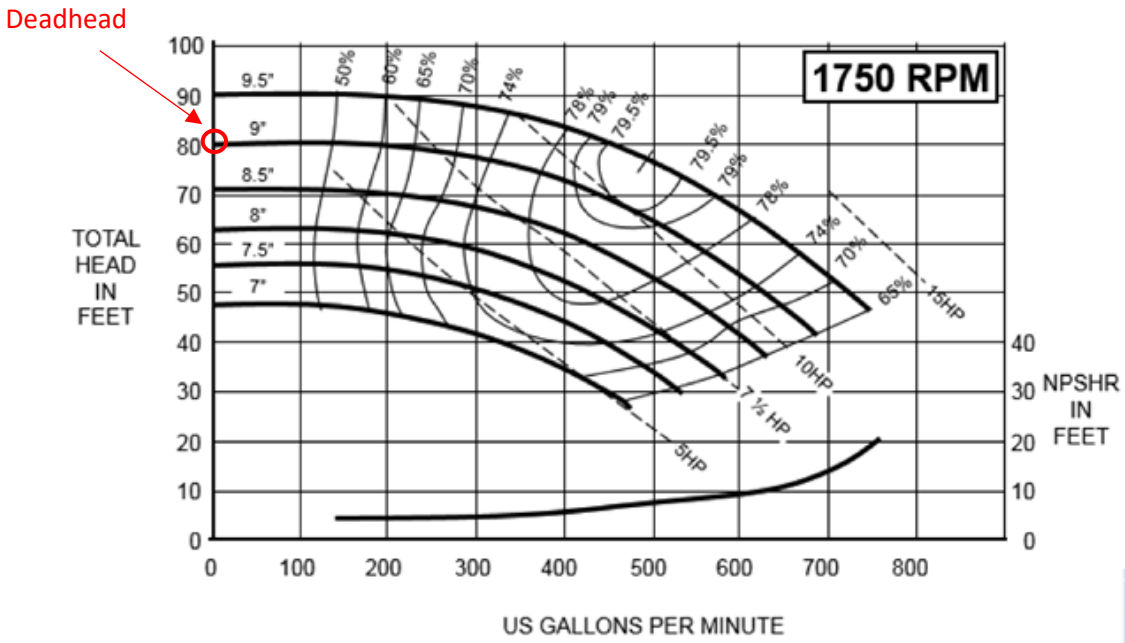
$$Maximum\ Blocked\ In\ Discharge\ (psig) = Suction\ Pressure\ (psig) + Deadhead\ Pressure\ (psig)$$

It should be noted that the suction pressure is largely dependent on the type of scenario being examined and can incorporate many different items, notably hydrostatic head. For example, if there is significant liquid level in the upstream vessel, hydrostatic pressure may contribute to the suction pressure, or if there is a liquid overfill scenario for a tower, the suction pressure may be determined as the sum of the vessel accumulation pressure (pressure in vessel when PSV is relieving) and the hydrostatic pressure.

Example

What is the maximum blocked in discharge pressure of the centrifugal pump transporting water with a 9” diameter impeller? The pump curve is provided in Figure 1 of this Tech Tip and the pump suction pressure is known to be 35 psig.

1. Refer to Pump Curve to find the Pump Deadhead Pressure



For a 9” impeller, the deadhead pressure is 80 ft.

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2. Convert Deadhead Pressure from Feet of Head to Psig

$$P\ (psig) = 0.433\ \times H\ (ft) \times SG$$

For water, the specific gravity is 1. The total head in feet / deadhead pressure from Step 1 is 80 ft. Therefore, the following applies:

$$P\ (psig) = 0.433\ \times 80\ ft \times 1$$

$$P\ (psig) = 34.64\ psig$$

3. Calculate Maximum Blocked in Discharge Pressure by adding Deadhead Pressure and Suction Pressure

$$Maximum\ Blocked\ In\ Discharge\ (psig) = Suction\ Pressure\ (psig) + Deadhead\ Pressure\ (psig)$$

$$Maximum\ Blocked\ In\ Discharge\ (psig) = 35\ psig + 34.64\ psig$$

$$\boxed{Maximum\ Blocked\ In\ Discharge\ (psig) = 69.64\ psig}$$

Resources

Source information for Figures

Figure 1 – Centrifugal vs. Positive Displacement Pump Curves:
https://www.pipeflow.com/software-technical-support/pipe-flow-expert-positive-displacement-pumps

Figure 2 – Centrifugal Pump Curve:
https://www.pumpsandsystems.com/understanding-pump-curves

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About the Author:

Ms. Jasmin Dhaliwal is a Senior Engineer at Risk Management Professionals and has been involved in a variety of activities associated with the California Accidental Release Prevention Program (CalARP), Environmental Protection Agency's Risk Management Plan (RMP) and Occupational Safety and Health Administration's Process Safety Management (PSM) Program. She specializes in facilitating Process Hazard Analysis (PHA) studies using the Hazard and Operability (HAZOP) and Layer of Protection Analysis (LOPA) methodologies.