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Hydraulic Transients in Storage Caverns

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Abstract

Hydraulic transients in fluids, also known as *waterhammer*, occur when steady-state flow conditions are interrupted. Pressure waves resulting from hydraulic transients are often heard or felt when a valve is quickly closed or the flow rate in/out of a cavern is rapidly altered. These phenomena are caused by the fluctuation of fluid momentum, which results in a transient change of the pressure head.

This change in pressure head (ΔH_p) has been recognized for a very long time but only described accurately since the late 19^{th} century. In one dimension, a single equation relates the ΔH_p to the speed of sound in the fluid (pressure wave velocity, c) multiplied by the change in fluid speed (magnitude of velocity change, ΔV) divided by gravitational acceleration (g), such as $\Delta H_p = -\frac{c\Delta V}{g}$. This equation shows that a large decrease in fluid velocity will result in a proportionally large increase of pressure head.

However, this formulation alone proves insufficient for determining how to properly operate valves on a storage cavern. Take for example the closure of a brine wellhead ESD valve, which may be triggered during a product overfill event. If the ESD valve is closed slowly over a long duration $\left(\frac{\Delta V}{\Delta t} \approx 0\right)$, the transient pressure increase resulting from the valve closure will be minimal, but this would allow for a substantial volume of product to rise in the brine string. Alternatively, a rapid ESD valve closure will minimize the volume of product in the brine string, but this abrupt change of brine velocity (in the hanging string) will result in a very large transient increases of pressure. If this situation is not handled properly, e.g., improper ESD valve closure duration, these pressure spikes could be catastrophic.

This paper will present an overview of calculations associated with the transient wave problem and an example of wave propagation in a bar. Then, taking concepts from this example and expanding on them, a description of hydraulic transients and a case study on hydraulic transients in a cavern will be provided. This case study will demonstrate how the proper brine wellhead ESD valve closure duration may be chosen such that transient pressure increases and product volume in the hanging string may be limited.

Key words: Cavern Hydraulics, Computer Modeling, Waterhammer