WHAT'S THE DIFFERENCE?

HDPE PVC

A Functional Comparison
- DR for DR -

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When comparing differences in a materials performance characteristics, such as between HDPE and PVC, it is important to make sure that you are making an accurate and equal comparison of the same characteristic exhibited in an identical situation. The following graphs are used to show the differences found in the pressure class performance exhibited by HDPE SDR 17 and PVC DR 18 in relation to a common occurrence found in all water distribution systems; that being fluctuations (many time sudden and significant) in the flow velocity of water.

In the following graphs, the **BLUE LINE** will depict PVC DR 18 Pressure Class 150 pipe and the **ORANGE LINE** will depict HDPE SDR 17 Pressure Rated for 100 psi operations. It is important for us to note and to understand from the beginning of this comparison that the term PRESSURE CLASS does not - and never has had the same performance definition for HDPE as it does for PVC. For the purpose of providing an equitable comparison we will be referring to the **WORKING PRESSURE RATING** of each material in an identical system scenario.

**NOTE**

In the most general sense, the **WORKING PRESSURE RATING** is the maximum pressure you can put a thermoplastic pipe (amorphous and semi-crystalline) under all normal operating conditions and expect no ruptures during its service life (i.e. field pressure rating, not laboratory).
The operational limits of PVC are categorized in terms of PRESSURE CLASS. The term PRESSURE CLASS indicates the pipe’s **maximum allowable operating pressure (also known as it’s maximum working pressure rating “WPR”)** and is based on the PVC’s pressure rating (maximum operating pressure @ 0 fps with no allowance for surge) minus a surge potential that is calculated from a baseline flow velocity of 2 fps.

**EXAMPLE:**

PVC - DR 18 - Pressure Class 150 has a long term fatigue service life based on a zero velocity total pressure capacity of 188 psi. It has a **maximum allowable operating pressure** (WP) of 150 psi with a surge allowance of 38 psi based on a 2 fps flow velocity.

\[
188 \text{ (PR)} - 38 \text{ (Ps)} = 150 \text{ (WP)} = 150 \text{ PC}
\]

The Pressure Class for a PVC pipe is directly related to the pipes specific DR. The ridged PVC material can only accommodate anticipated pressure surges by de-rating the maximum allowable operating pressure (Working Pressure) in direct proportion to any changes experienced in system flow velocities. As flow velocities increase more of the PVC pressure capacity is consumed by surge pressure. Surge pressures are a result of changes in flow velocity and are approx. 19 psi per every 1 fps change in a DR 18 PVC pipe. Any increases in flow velocity will require a reduction in the allowable operating pressure (working pressure) in order to ensure that the surge capacity of the material will not be exceeded and the long term fatigue service life will not be reduced.
Pressure Class Comparison for PVC and HDPE Pipes as a Function of Flow Velocity of Water

Due to the significant material differences and performance characteristics found in PVC and HDPE, the term PRESSURE CLASS has no equivalent definition that effectively links the two materials together. Today, when looking to implement the use of HDPE based on an equivalent PVC Pressure Class, it is imperative that you know beforehand what the range of your WORKING PRESSURES (operational pressures) will be and then you need to match your systems specific operational needs to the performance characteristics of the HDPE’s SDR which is typically categorized as the PRESSURE RATING.

HDPE’s PRESSURE RATING is based on its maximum allowable operating pressure and it indicates the upper limit of the pipe’s constant operating pressure (also known as it’s working pressure rating “WPR”). This PRESSURE RATING not only identifies the constant and sustainable operating pressure that does not have to be changed or reduced in relation to changes in the flow velocity of water; it also includes the pipes ability to accommodate an infinite number of anticipated pressure surges at 150% of its stated operating pressure in addition to accommodating a highly significant number of pressure surges at 200% of its stated operating pressure.

EXAMPLE:

\[
\begin{align*}
50 \text{ (50\% of PR)} & \quad 150 \text{ psi (for infinite surges)} \\
100 \text{ (PR)} + & = \\
100 \text{ (100\% of PR)} & \quad 200 \text{ psi (for occasional surges)}
\end{align*}
\]
Having distinguished the differences in the terms “PRESSURE CLASS” and “PRESSURE RATING” as it is used for PVC and HDPE, and having defined some of the performance limitations associated with the interpretations of those terms; we will now look at some of the implications of the two materials using a comparative scenario based on the parameters established by each of the materials related pressure class and pressure rating. The first area we will notice is an area where both materials function equally DR for DR. The light blue area highlighted in this chart identifies the specific operational range found within a distribution system where HDPE SDR 17 pressure class 100 and PVC DR 18 pressure class 150 will perform equally well. You will note that within this area the operating pressures (working pressures) do not exceed 100 psi and the flow velocities do not exceed 5 fps.
Pressure Class Comparison for PVC and HDPE Pipes as a Function of Flow Velocity of Water

In this chart we are able to identify a small area where the **STATIC STRENGTH** of the PVC (due to its higher hoop-stress capability) is actually superior to the HDPE. It must be noted however that we are talking specifically about static strength not dynamic strength.

The ridged material characteristic of an amorphous plastic such as PVC makes it an ideal choice for pressure containment systems as long as the system **will not** experience any dynamic changes or cyclic events (pumps turning on and off - water hammer - etc.) within the system. The trade off for having a greater static strength however, is a significant reduction in the fatigue or cyclic resistance of the material. It is for this reason that the maximum operating pressure of an amorphous plastic such as PVC must be de-rated in relation to the flow velocities it will experience. The surge pressures experienced within a closed system that are associated with sudden or cyclic changes in flow velocity will:

a) quickly subject the material to pressures beyond its capacity (short term result), or

b) bring the material to its point of fatigue failure (long term result)
In this chart we begin to see that the flexible, semi-crystalline material characteristic of HDPE exhibits a higher capacity for tolerating surge pressures. This is due to the materials interconnected and entangled molecular structure. The unique performance characteristic of the HDPE polymer chains disentangling (flexing) under sudden stress and then returning to its normal state, provides the HDPE with the ability to absorb some of the energy generated by the pressure surge. This inherent mechanism provides the HDPE with a built in safety factor for surge stresses. As we can see in this graph, up to 150% of the HDPE’s Pressure Rating (PR) is safe for an infinite number of cycles. This gives HDPE a unique operational area (indicated by the darker blue area) that allows for the working pressure in a HDPE system to remain constant and unchanged at flow velocities of 5 fps and lower with no de-rating required.
Pressure Class Comparison for PVC and HDPE Pipes as a Function of Flow Velocity of Water

We all know that in the “real world” most systems are going to experience flow velocities that exceed 5 fps. That requires a closer look at the dynamic effect that changes in flow velocity will have on the different pipe materials. We stated earlier that as flow velocities increase, the maximum allowable operating pressure (working pressure) in a PVC system must be de-rated in direct proportion to the flow velocity change. This critical area is highlighted in red and as can be seen, the maximum allowable working pressure must be significantly reduced in order to accommodate the increases in surge pressure. This de-rating and reduction of working pressure must be done so that the maximum working pressure + pressure surge, will not exceed the surge capacity of the pipe system (indicated by dotted green line) and compromise both the systems overall integrity and cause a reduction in the PVC’s fatigue life cycle. Pressures that go beyond this limit indicated by the green line exceed system limits as defined by the AWWA for PVC pipe.

(The fatigue life of PVC pipe is not all inclusive. It must be calculated for each DR using a specific flow velocity, at a specific static pressure (hoop stress). In the case of DR 18 PC150 - the fatigue life of the PVC pipe is determined to be able to withstand 48,965 surge events before material failure takes place. This equates to 2 surge events per day for 50 years or 6 surge events per hour for 15 years).

[2 cycles = 1 Surge Event, 97,890 cycles = 48,945 surge events]
Pressure Class Comparison for PVC and HDPE Pipes as a Function of Flow Velocity of Water

Once again, even with flow velocities exceeding 5fps, the unique performance characteristics of HDPE exhibit a higher tolerance for resisting surge pressures. An additional inherent safety factor up to 200% of its Pressure Rating (PR), gives HDPE a unique safety area (indicated by the yellow area) that allows for the operating pressure in a HDPE system to remain constant and unchanged at flow velocities between 5 fps and 10 fps still with no de-rating required. All the while maintaining the capability of accepting and resisting a finite yet highly significant number of occasional cyclic events, surge events or sudden changes in pressure without having any impact on the long term performance of the pipe material

(Like PVC, the fatigue life of HDPE pipe is not all inclusive. It must be calculated for each DR using a specific flow velocity, at a specific static pressure (hoop stress). In the case of SDR 17 - the fatigue life of the HDPE pipe is determined to be able to withstand > 5 million surge events which is equivalent to about 273 surge events per day - or 11 surge events per hour for 50 years - or 6 events per hour for > 190 years.)

[2 cycles = 1 Surge Event, 10 million cycles = 5 million surge events]
Pressure Class Comparison for PVC and HDPE Pipes as a Function of Flow Velocity of Water

As you can see by the area highlighted in green, what we have is a significant area where DR for DR, the performance capabilities of the HDPE are clearly superior to those of the PVC.
Pressure Surge in DR 18 PVC System
(Operating at 80 psi @ 8 fps)

Pressures above the green line exceed AWWA limits for PVC pipe according to AWWA C900 & AWWA M23.

Maximum Allowable Operating Pressure should not exceed 47 psi.

Pressure Surge in SDR 17 HDPE System
Operating at 80 psi @ 8 fps

Safe Area For Occasional Surges 4.8 fps - 10 fps
(> 10 million cycles or 6 cycles per hour for 190 years)

Safe Area For Infinite Recurring Surges
(0 fps - 4.7 fps)

Operating Pressure does not need to be de-rated!
<table>
<thead>
<tr>
<th><strong>HDPE SDR 17</strong></th>
<th><strong>PVC DR 18</strong></th>
</tr>
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<tbody>
<tr>
<td>@ 80 psi @ 10 fps</td>
<td>@ 80 psi @ 10 fps</td>
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- **Semi-Crystalline Thermoplastic**
- **Pressure Rating** - 100 psi
- **Pressure Class** - 100
- **Working Pressure Rating** - 100 psi (remains constant no de-rating required)
- **Surge Capacity** - 200 psi Total (WP +
  - 50% of Pressure Rating for Infinite Surges, or
  - 100% of Pressure Rating for Occasional Surges
  
  (WP) 80 + (Ps) 85 = 185 psi

  This falls comfortably within the HDPE Pressure Class 100’s “Safe for Occasional Surge” zone.

- **Cyclic Resistance to material failure**
  >10 million events, or
  273 events per day for 50 years, or
  11 events per hour for 50 years, or
  6 events per hour for >190 years
- **Method of Joining** - Heat Fusion
- **Type of Restraints** - N/A in totally fused system

- **Amorphous Thermoplastic**
- **Pressure Rating @ 0fps (no surge allowance)** - 188 psi
- **Pressure Class** - 150
- **Working Pressure Rating** - 150 psi @ 2 fps

  WP must be decreased to no more than 47 psi because the flow velocity is at 8fps otherwise the surge capacity will be exceeded i.e. (WP) 47 + (Ps) 141 = 188 psi

  - **Surge Capacity** - 188 psi Total (WP + Ps)
    
    (WP) 80 + (Ps) 141 = 221

    The PVC Pressure Class 150 Surge Capacity in this scenario is exceeded by 33 psi according to AWWA C900 & AWWA M23

- **Cyclic Resistance** to material failure
  48,945 events, or
  2 events per day for 50 years, or
  6 events per hour for 15 years

  (assuming WP is correctly adjusted with flow velocity changes otherwise these figures will be significantly reduced)

- **Method of Joining** - Gasketed - Push On
- **Type of Restraints** - Bolt on, or Thrust Blocks