ABSTRACT

This paper explains what the $K_R$ value is and how it is used in calculations to determine pressure loss across the components of a piping system. Two worked examples compare rupture discs from Oseco and Fike, and illustrate the effect the different $K_R$ values have on the flow capacity of a piping system. Finally, there is a quick reference table showing the different $K_R$ values of rupture discs from four major manufacturers.

Contributors
David Parnell
Mike Quimby
Brandon Hentzen
Alan Wilson
Jeff Scoville
Laura Ball

US office: 1701 W. Tacoma, Broken Arrow, OK 74912
(918) 258-5626 | info@oseco.com | www.oseco.com

UK office: Alder Road, North Shields, Tyne & Wear NE29 8SD
+44 (0)191 293 1234 | sales@elfab.com | www.elfab.com

THE LOSS COEFFICIENT “K”

The concept of a loss coefficient “K” has been used for many years to define “minor” pressure losses in piping systems due to elbows, tees, fittings, valves, reducers and other components. Crane’s Technical Paper No. 410 Flow of Fluids Through Valves, Fittings, and Pipes, first published in 1957, describes the methods of using the loss coefficient to calculate overall flow rates and pressure drops.

The loss coefficient “K” is defined as:

$$K = \frac{\frac{h}{\sqrt{g}}}{\frac{\Delta P}{\frac{1}{2} \rho V^2}}$$

Therefore, $K$ is the pressure loss expressed in terms of the number of velocity heads. While $K$ is technically dependent upon the component geometry and Reynolds number, the dependence is strongest to geometry in fully developed turbulent flow. ASME assumes in its Code that this dependence is strictly on geometry.

THE OVERALL LOSS COEFFICIENT OF A PIPING SYSTEM

In most piping systems, there are several components that contribute to the overall “K” of the system. A simple example is a single pipe, with an entrance, one elbow and an exit. The total loss coefficient would be defined as:

$$K_{total} = K_{entrance} + K_{elbow} + K_{pipe} + K_{exit}$$

Several sources (including the Crane 410 paper) provide values for $K_{entrance}$, $K_{elbow}$, $K_{pipe}$ and $K_{exit}$. If a rupture disc is present in a piping system, it too will contribute to the total “K” of that system.

The designation for the loss coefficient of a rupture disc is “$K_R$”.

Therefore, a piping system with a rupture disc and two elbows would be defined by:

$$K_{total} = K_{entrance} + K_R + K_{elbow} + K_{elbow} + K_{pipe} + K_{exit}$$
WHY CAN I FIND OUT WHAT THE $K_r$ VALUE IS?

Prior to the 1998 revision of the ASME Code, the engineer did not have a reliable source of $K_r$ for rupture discs. API RP 521 gave an estimate of 1.5 for $K_r$, regardless of disc design, however this was a conservative value and did not reflect the actual $K_r$ value of many discs. For example, in the National Board NB-18 (known familiarly as the "Red Book"), there are several discs with rated $K_r$ above this value.

THE UD CODE STAMP

In 1998, a revision to the ASME Section VIII, Division 1 Code established a new code symbol stamp for rupture discs: the “UD” stamp. While the Code recognized rupture discs as acceptable pressure relief devices prior to this revision, there was no formal process for product certification. Very few manufacturers had performed flow testing of their products, and therefore the methodologies for sizing relief systems reflected in the ASME Code and API Recommended Practices (RP) were estimates at best. In the absence of a flow test, ASME BPVC VIII.1-2019 UG-137 (n) provides a generic $K_r$ value of 2.4.

The UD stamp requires any product carrying the stamp to be flow tested at an ASME PTC-25 accepted flow laboratory in the presence of a representative from the National Board of Boiler and Pressure Vessel Inspectors. Results of the flow testing are communicated directly to the user via the certified flow resistance factor ($K_r$) and minimum net flow area (MNFA) stamped on the disc tag. These values are published in the National Board NB-18, which also covers relief valves.

MINIMUM NET FLOW AREA (MNFA)

The minimum net flow area is used in relieving capacity calculations as defined in UG-127 (2)(a), “coefficient of discharge” method. The coefficient of discharge method is used when the disc discharges directly to atmosphere and is installed within eight pipe diameters of the vessel and within five pipe diameters of the outlet of the discharge piping (see Figure 1). The MNFA is the “A” (area) in the equation. A coefficient of discharge “$K_D$” of 0.62 is assumed.

It is important to realize that the coefficient of discharge is a different dimensionless parameter than $K_r$. The most common error that we encounter is users applying the manufacturer’s $K_r$ to coefficient of discharge calculations. This can be very dangerous, as increasing “$K_r$” above 0.62 may result in selection of too small a rupture disc for the given application.

WHAT IS $K_r$?

While this seems like a simple question, it is actually very difficult to answer unless you know how your system is configured.

A pressure relief system with only short pipe runs with no elbows or other fittings will have a very strong dependence on the rupture disc for its overall pressure drop, as the disc makes the most significant contribution to the overall system. On the other hand, a pressure relief system with pipe runs in the tens of feet, several elbows, tees and so on, would not be as dependent upon the rupture disc for pressure loss.

This is best illustrated by the following two examples:
EXAMPLE 1

A rupture disc is installed with short pipe runs between inlet and outlet. This configuration shown in Figure 1. The following calculations illustrate the difference in pressure drop and rated flow between an OSECO FAS (forward acting scored) with \( K_R = 0.22 \) and a Fike Poly-SD (forward acting scored) with \( K_R = 0.99 \). It assumed that the pipe friction factor \( f \) is 0.025 for a 3” pipe diameter.

Pressure drop is directly proportional to \( K_{\text{total}} \), therefore the Fike Poly-SD relief system will have a 38% higher pressure drop than the Oseco FAS.

As flow capacity is inversely proportional to the square root of pressure drop, the Fike Poly-SD system would have a flow capacity 15% less than the Oseco FAS for the same pressure drop limitation.

EXAMPLE 2

A rupture disc is installed in a pressure relief header with a long pipe run (100 pipe diameters) and an elbow (Figure 2). The same two discs from Example #1 are once again compared. It is assumed that the first pipe run is 10 pipe diameters, the final pipe run is 90 pipe diameters.

\( K_{\text{total}} \) for both systems increased as the contributions from the elbow and long pipe run are added. The rupture disc contributes less to the overall pressure drop. Therefore, the Fike Poly-SD relief system now has a pressure drop that is only 17% more than the OSECO FAS. Flow capacity is only reduced by 7.5%.

The only statement that can be made with certainty in all pressure relief system designs is that any system will have the lowest pressure drop (therefore highest flow) when the rupture disc with the lowest \( K_R \) is used.
WHERE CAN I FIND THE $K_R$ VALUE FOR A RUPTURE DISC?

The easiest place to find it is on the rupture disc tag itself. But what if you would like to know it before you buy the disc? Most manufacturers provide $K_R$ tables by model number in their product catalogs. The National Board of Boiler and Pressure Vessel Inspectors publishes a list of all rupture discs, termed NB-18, both by model number and manufacturer. The NB-18 can be downloaded from the National Board website at [http://www.national-board.com](http://www.national-board.com).

For the convenience of the reader, we have presented a table of major manufacturer’s models by $K_R$, as taken from the National Board NB-18.

<table>
<thead>
<tr>
<th>FLOW</th>
<th>TYPE</th>
<th>SEAT</th>
<th>OSECO-ELFAB</th>
<th>BS&amp;B</th>
<th>CONTINENTAL</th>
<th>FIKE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MODEL $K_R$</td>
<td>MODEL $K_R$</td>
<td>MODEL $K_R$</td>
<td>MODEL $K_R$</td>
</tr>
<tr>
<td>Forward</td>
<td>Scored</td>
<td>Flat</td>
<td>FAS 0.22</td>
<td>GFN 0.55</td>
<td>Micro-X 0.29</td>
<td>Poly-SD 0.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FST 2.29</td>
<td></td>
<td>Micro-XV 0.29</td>
<td></td>
</tr>
<tr>
<td>Reverse</td>
<td>Scored</td>
<td>Flat</td>
<td>PRO+ 0.29</td>
<td>SKr 0.37</td>
<td>RCS 0.35</td>
<td>SRL 0.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PRO+KRGL 0.69</td>
<td>Sigma 0.38</td>
<td>LOTRX 0.36</td>
<td>SRX 0.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>OPR+ 0.78</td>
<td>ECR 0.58</td>
<td>ULTRX 0.36</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>OPK+ 1.5</td>
<td>CSR 1</td>
<td>STARX 0.38</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PSR 2.13</td>
<td>S-90 1.13</td>
<td>MINITRX 0.46</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCR 2.17</td>
<td>RLS 1.14</td>
<td>CD90XXX 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>Standard</td>
<td>Flat</td>
<td>STD 0.88</td>
<td>B 0.71</td>
<td>STD 1.13</td>
<td>CP 3.47</td>
</tr>
<tr>
<td></td>
<td>Standard w/VS</td>
<td>Angular</td>
<td>STDV 1.98</td>
<td>BV 0.8</td>
<td>STD-V 3.11</td>
<td>CPV 3.47</td>
</tr>
<tr>
<td>Forward</td>
<td>Composite</td>
<td>Flat</td>
<td>(F)CO 0.5</td>
<td>CDC 0.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Composite w/VS</td>
<td></td>
<td>(F)COV 2.37</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Composite FLCO 1.7</td>
<td>AV 4.35 Enviro-Seal 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>Scored</td>
<td>Sanitary</td>
<td>FASS 10.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse</td>
<td>Scored</td>
<td>Sanitary</td>
<td>GFRS 23.47</td>
<td>Sanitrx 3.18</td>
<td>SR-H 1.83</td>
<td></td>
</tr>
</tbody>
</table>