The Use of Certified K_R for Rupture Disks

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THE UD CODE STAMP

The ASME Section VIII, Division 1, 1998 code established a new code symbol stamp for rupture disks in 1999 called "UD". While the Code recognized rupture disks 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, therefore the methodologies for sizing relief systems reflected in the ASME Code and API Recommended Practices (RP) were estimates at best.

The new UD stamp now 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 disk tag. These values are also published in the National Board Red Book, which also covers relief valves.

WHAT DOES K_R MEAN?

The concept of a loss coefficient "K" has been used for many years to define piping system "minor" losses due to elbows, tees, fittings, valves, reducers, etc. Crane published a Technical Paper No. 410 in 1957, "Flow of Fluids Through Valves, Fittings, and Pipe", that describes the methods of using the loss coefficient to calculate overall flow rates and pressure drops.

The loss coefficient "K" is defined as:

$$K = \frac{h_L}{\left(\frac{V^2}{2g}\right)} = \frac{\Delta P}{\frac{1}{2}\rho V^2} \qquad (1)$$

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.

HOW DO I USE K_R?

The concept of a loss coefficient "K" has been used for many years to define piping

In most piping systems, there are several components that contribute to the overall "K" of the system. For example, a piping system with a rupture disk and two elbows would be defined by:

$$K_{total} = K_{entrance} + K_R + K_{elbow} + K_{elbow} + K_{pipe} + K_{exit} \qquad (2)$$

There are several sources (including the Crane 410 paper) that can provide $K_{entrance}$, K_{elbow}, K_{pipe}, and K_{exit}. Prior to the 1998 revision of the ASME Code, the engineer did not have a reliable source of K_R for the rupture disk. API RP521 gave an estimate of 1.5 for K_R, regardless of disk design, etc. In most cases this was a conservative value. However, as evidenced by the National Board Red Book, there are several disks with rated K_R above this value.

WHAT IMPACT WILL A RUPTURE DISK K_R HAVE ON MY SYSTEM?

While this seems like a simple question, it is really 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 disk for its overall pressure drop, as the disk 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, etc. would not be as dependent upon the rupture disk for pressure loss. This is best illustrated by the following examples:

EXAMPLE 1

A rupture disk 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.

OSECO FAS	**FIKE POLY-SD**
$K_{entrance} = 0.5$	$K_{entrance} = 0.5$
$K_{piperun1} = f\frac{L}{D} = (0.025)(8) = 0.20$	$K_{piperun1} = f\frac{L}{D} = (0.025)(8) = 0.20$
$K_R = 0.22$	$K_R = 0.99$
$K_{piperun2} = f\frac{L}{D} = (0.025)(5) = 0.125$	$K_{piperun2} = f\frac{L}{D} = (0.025)(5) = 0.125$
$K_{exit} = 1.0$	$K_{exit} = 1.0$
$K_{total} = 2.045$	$K_{total} = 2.815$

Pressure drop is directly proportional to K_{total} (per Equation 1), therefore the Fike Poly-SD relief system will have a 38% higher pressure drop than the OSECO FAS. 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.

<u>EXAMPLE 2</u>

A rupture disk is installed in a pressure relief header with a long pipe run (100 pipe diameters) and an elbow (Figure 2). The same two disks 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.

OSECO FAS	**FIKE POLY-SD**
$K_{entrance} = 0.5$	$K_{entrance} = 0.5$
$K_{piperun1} = f\frac{L}{D} = (0.025)(10) = 0.25$	$K_{piperun1} = f\frac{L}{D} = (0.025)(10) = 0.25$
$K_R = 0.22$	$K_R = 0.99$
$K_{elbow} = 0.34$	$K_{elbow} = 0.34$
$K_{piperun2} = f\frac{L}{D} = (0.025)(90) = 2.25$	$K_{piperun2} = f\frac{L}{D} = (0.025)(90) = 2.25$
$K_{exit} = 1.0$	$K_{exit} = 1.0$
$K_{total} = 4.560$	$K_{total} = 5.330$

K_{total} for both systems increased as the contributions from the elbow and long pipe run are added. The rupture disk 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 disk with the lowest K_R is used.

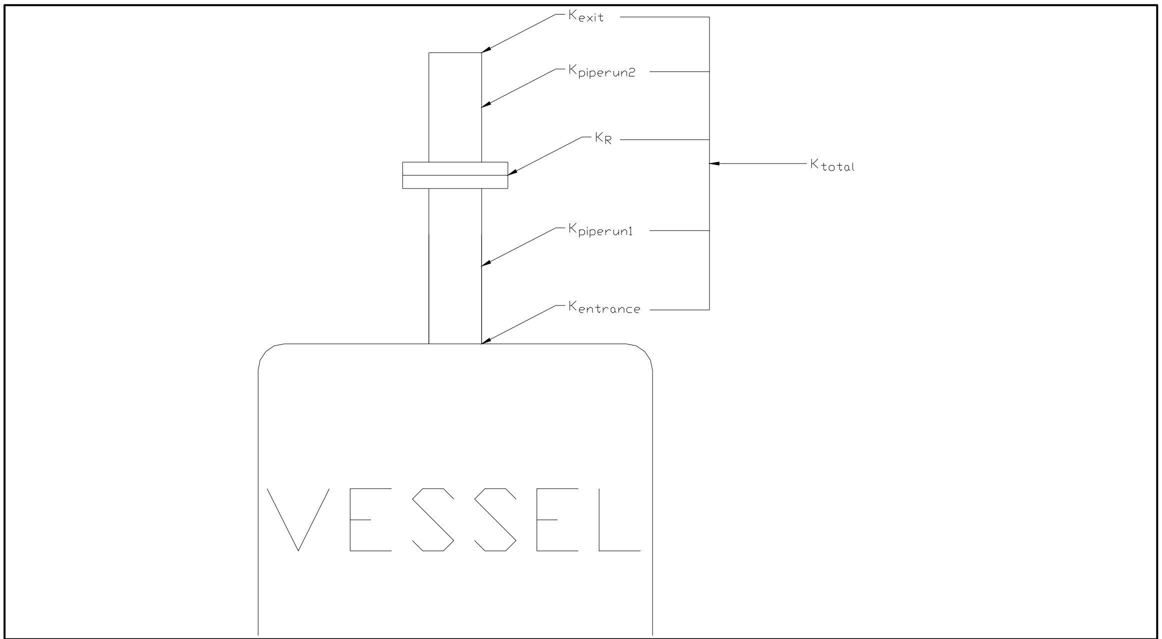

Figure 1, Disk discharging directly to atmosphere.

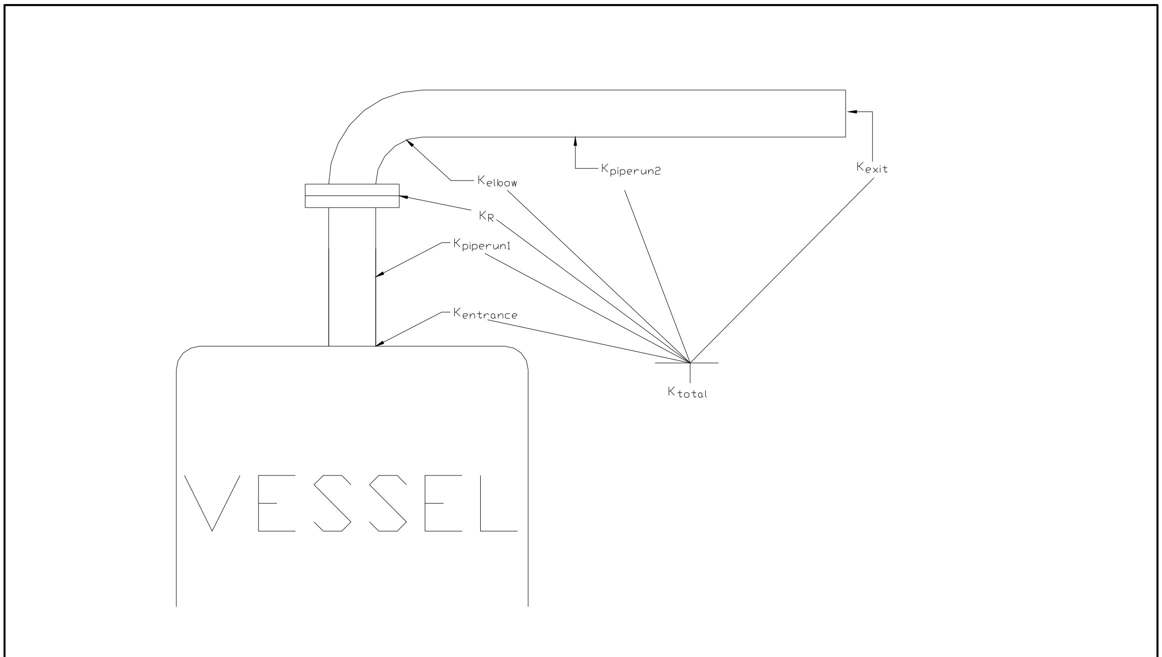

Figure 2, Disk discharging through pipe header with elbow.

WHAT IS 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 disk 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 since the new code was published is users applying the manufacturer's K_R to coefficient of discharge calculations. This can be very dangerous, as increasing "K_D" above 0.62 may result in selection of too small of a rupture disk for the given application.

WHERE CAN I FIND THE K_R FOR A RUPTURE DISK?

The easiest place to find it is on the rupture disk tag itself. What happens if you would like to know it before you buy the disk? Most manufacturers provide K_R tables by model number in their product catalogs. The National Board of Boiler and Pressure Vessel Inspectors publishes an annual "Red Book" that lists all rupture disks both by model number and manufacturer, as well. The "Red Book" can also be downloaded as an Adobe Acrobat pdf file from the National Board web site at http://www.nationalboard.com.

For the convenience of the reader, we have presented a table of major manufacturer's models by K_R.

Major Manufacturer K_r table from National Board Red Book

DIR	TYPE	SEAT	OSECO		BS&B		CONTINENTAL		FIKE	
			MODEL	K_r	MODEL	K_r	MODEL	K_r	MODEL	K_r
Forward	Scored	Flat	FAS FST	0.22 2.29	GFN	0.55	Micro-X Micro-XV	0.29 0.29	Poly-SD	0.99
Reverse	Scored	Flat	PSR PCR	2.13 2.17	SKr Sigma ECR CSR S-90 RLS FRBA	0.37 0.38 0.58 1.00 1.13 1.14 2.19	RCS LOTRX ULTRX STARX MINITRX CD90XXX	0.35 0.36 0.36 0.38 0.46 1.00	SRL SRX	0.38 0.99
Reverse	Knife-Blade	Flat	PLR	3.17	JRS	0.31	ZAP KBA	5.88 3.62	MRK	1.56
Forward	Standard	Angular	STD	0.88	B	0.71	STD	1.13	CP	3.47
Forward	Standard w/VS	Angular	STDV	0.66	BV	0.80	STD-V	3.11	CPV	3.47
Forward	Composite	Flat	(F)CO	0.50			CDC	0.34		
Forward	Composite	U-Seat	(U)CO	0.58						
Forward	Composite	Angular	CO	1.00	D	1.19	CDC	1.81	HO	2.02
Forward	Composite w/VS	Angular	COV	1.22	DV	1.19	CDCV	4.00	HOV	2.02
Forward	Flat Composite	Flat	FLCO	1.7	AV	4.35	Enviro-Seal	2.00		
Forward	Scored	Sanitary	FASS	10.75						
Reverse	Scored	Sanitary	PLR-S	19.5	GFRS	23.47	Sanitrx	3.18	SR-H	1.88