Application of K_r Factor for Accu-Shear Devices

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By: Curtis Schmidt, PE

BACKGROUND OF UD STAMPED DEVICES (ACCU-SHEAR)

The ASME Section VIII, Division 1, 1998 code established a new code symbol stamp for non-reclosable pressure relief devices requiring a manual reset called “UD”. Since this time breaking pin devices have been brought under the umbrella of the "UD" designation. The code now recognizes breaking pin devices carrying the "UD" stamp as acceptable pressure relief devices when used alone.[i]

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 (Kr) and minimum net flow area (MNFA) stamped on the device tag. These values are also published in the National Board Red Book, which also covers rupture disks and relief valves.[ii]

Kr DEFINED

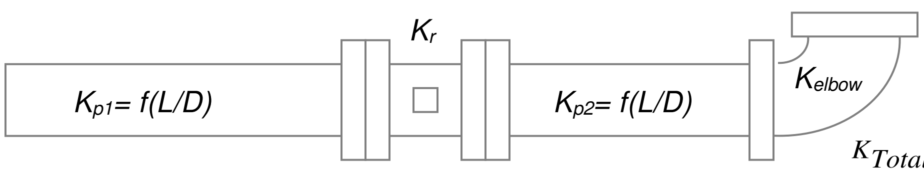
The use of K to quantify loss in the line due to pipe, fittings, valves, reducers and so on has a long history in the industry. Crane Co published a Technical Paper No. 410 in 1957, "Flow of Fluids Through Valves, Fittings and Pipe" that describes the many different applications of this loss coefficient, including how to calculate overall flow rates and pressure drops.

ASME PTC-25 outlines the specific methods of calculating Kr and the specific test set ups required to have a certified loss coefficient. ASME code neglects many of the smaller factors that influence K and the code assumes that K is strictly dependence on its primary factor, geometry. [iii] *(This is NOT Kv as in the metric version of the Cv, Kr is the loss coefficient and independent of size)*

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

DETERMINATION OF K FOR SYSTEM

The Kr factor of the Accu-Shear device can be added up along with the loss coefficients of the pipe, fittings and other components of the system for flow calculations.



$$K_{Total} = K_{p1} + K_{p2} + K_r + K_{elbow}$$

USE OF 'K' IN CALCULATING CHANGE IN PRESSURE ACROSS DEVICE

For compressible flow the equations get somewhat complicated however the Crane manual presents a few options, one of which will be outlined below.

$$\Delta P = 0.0001078 \frac{K \rho v^2}{Y^2}$$

$\rho =$ *weight density of fluid in* lbs / ft^3

$v =$ *mean velocity of flow, in* ft / s

$Y =$ *correction factor for compressible flow, value defined on A - 22 of Crane 410 paper*

The correction factor, Y, is based on both the coefficient of resistance and the ratio of the change in pressure to the absolute pressure. The ANSI 150 Accu-Shear devices are certified for a flow coefficient of 3.71 and as such the Y factors for Air (k=1.4) are listed below for reference.[iv]

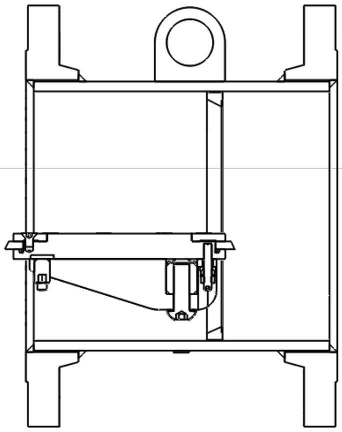
$\frac{\Delta P}{P_{Inlet-Absolute}}$	Y
0.20	0.89
0.30	0.84
0.40	0.79
0.50	0.74
0.60	0.69
0.687	0.65

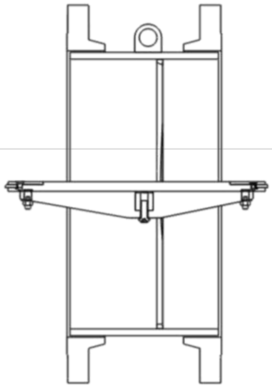
LIMITATION AND CONSERVATISM OF 'K' WHEN USED FOR ACCU-SHEAR DEVICES

Though the above methodology is a valid manner to calculate flow across the Accu-Shear devices it tends to be very conservative. Using the resistive coefficient method to certify the flow of the Accu-Shear line assumes that the geometry is simply scaled up and down for different valve sizes. This is not the case. The crane technical paper discusses this limitation of the resistance coefficient K in chapter 2 and illustrates in figure 2-13.

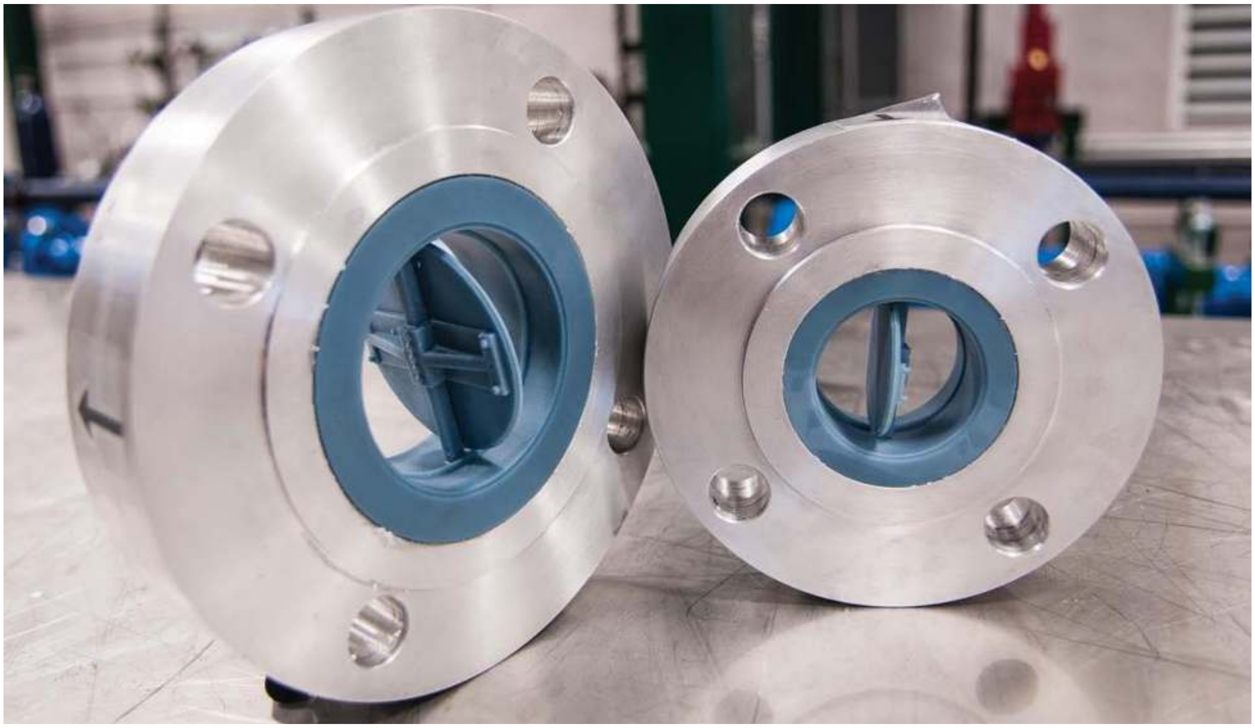
> *"The resistance coefficient K would theoretically be a constant for all sizes of a given design or line of valves and fittings if all sizes were geometrically similar. However geometric similarity is seldom, if ever, achieved because the design of valves and fittings is dictated by manufacturing economies, standards, structural strength, and other considerations." -Crane 410, page 2-8*

Though as part of certification ASME PTC-25 specifies that K values of different devices within the line can deviate no more than 3 standard deviations from each other this still allows for a wide amount of scatter. The figure below shows an 8 inch device (left) next to a 24 inch device (right) to illustrate that the Accu-Shear does not scale well.





In determining the certified value of Kr for the device ASME takes into account this scatter and picks a conservative value to encompass this scatter. So the more scatter the more conservatism there is in the certified value of K. For example the Accu-Shear line had an average K value of 1.91 but was certified at 3.71 due to scatter in the 9 different tests of three different sized devices ranging from a 1/8 scale model of the 8 inch to a 1/8 inch scale model of the 24 inch. Below is a picture of the models used for flow certification at the national board.



WHAT IS MNFA (MINIMUM NET FLOW AREA) AND WHEN IS IT USED

The MNFA is only used to rate the capacity of the device when the *"Coefficient of Discharge"* method is employed to rate flow. This method may only be used in unique circumstances when the following conditions are met:

i. The pipe discharged directly to the atmosphere
ii. The Accu-Shear device is installed within 8 pipe diameters of the beginning of the piping from the pressure vessel
iii. The Accu-Shear device is installed within 5 diameters of the end of the discharging pipe

The specifics of this method are outlined in the ASME Pressure Vessel Code Section VIII.

WHAT ABOUT THE Cv FACTOR?

The Cv factor is typically used for fluid control valves rather than pressure relief devices however a conversion exists in the crane 410 technical paper (A-31), the equation used is below (where d is the diameter in inches of the line) a graphical figure is found in the Crane 410 paper:

$$C_V = \frac{29.9d^2}{\sqrt{K_r}}$$

Using the above formula and the data from the National Board flow tests on the 3D 1/8 scale printed models used for flow certification estimates for Cv values can be found and are shown in the table below:

Approximate **Cv Values** from Crane Manual Conversion

Size	Model	Coefficient of Resistance (Kr) = 3.71*	Coefficient of Resistance (Kr) = 1.91**
8	LP	993	1,385
8	HP	993	1,385
10	LP	1,552	2,163
10	HP	1,552	2,163
12	LP	2,235	3,115
12	LL	2,235	3,115
12	HP	2,235	3,115
14	LP	3,043	4,240
14	HP	3,043	4,240
16	LP	3,974	5,539
16	HP	3,974	5,539
18	LP	5,030	7,010
18	HP	5,030	7,010
20	LP	6,209	8,654
20	HP	6,209	8,654
24	LP	8,941	12,462
24	HP	8,941	12,462

*** ***Certified*** *Coefficient of Resistance for Entire Accu-Shear Line, actual flow capacity will fall above that predicted by this coefficient*
**** ***Average*** *Coefficient of Resistance, actual flow capacity will fall above or below that predicted by using this coefficient*

FURTHER ASSISTANCE IN FLOW CAPACITY PREDICTION

Enviro Valve Inc is currently building a library of flow data for the Accu-Shear Device for different fluids, pressures, temperatures and other flow conditions based on experimental and CFD analysis as this provides much more usable data than the estimates outlined above. If you have a specific flow coefficient request and feel that the conservative certified Kr value will not meet your needs please do not hesitate to ask us and we can compute specific flow capacity for your application based on past experience and CFD modeling.

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[i] ASME, "Rules for Construction of Pressure Vessels" BPVC-VIII Division I 2013, UG-125(e)
[ii] Scoville, Jeff "The Use of Certified KR for Rupture Disks" OSECO
[iii] Scoville, Jeff "The Use of Certified KR for Rupture Disks" OSECO
[iv] Crane Co, "Flow Of Fluids through Valves, Fittings and Pipe" Technical Paper No. 410, published 1988