We Solve Control Valve Problems®

Control Valve Trim Fluid Exit Kinetic Energy and Velocity

History and Basis

White Paper

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Background:

In the ISA publication "Practical Guides for Measurement and Control – Control Valves," Reference 1, there is a discussion regarding the use of the valve trim fluid kinetic energy as design criteria. When presented to many users in the control valve industry a number of questions arise. The answer to many of these questions along with a historical background is presented below. I have tried to answer each question so that they are independent and thus could be lifted separately and provided to a customer.

1. **Question:** What are the kinetic energy design criteria?

   Fluid Kinetic Energy = $\rho V^2/2g$, where ρ is the density and V is the velocity of the fluid. This expression is also referred to as the dynamic pressure, kinetic energy density and as velocity head in different fluid flow applications.

Response: It is a criterion associated with the valve design and the valve's application. The design process it to first select a valve style and size to assure it will allow all of the application's pressure drop and flow requirements. This initial step also includes material selection and body design to assure the appropriate pressure boundary codes are also met. Then *as a final verification* that the selected design will result in a good process control element with low operating cost, the fluid kinetic energy exiting the valve trim is calculated and compared to the criteria in Table 12.3 of the ISA Practical Guide on Control Valves. This table is shown below. Low operating costs are realized through low wear and erosion of the trim parts, infrequent maintenance and a low vibration and quiet installation. The energy criteria account for the impact of the fluid density and its velocity within the same parameter.

The use of the kinetic energy density expression in fluid flow can be traced back more than 100 years. A couple of significant references relative to fluid flow through pipes, valves and other restrictions in the 1930s are presented in *Dimensional Analysis* by Bridgeman, Reference 2, and a Crane Company publication in 1935 titled "Flow of Fluids and Heat Transmission, Reference 3. The Crane publication was the precursor to the well known *Technical Publication 410*, Reference 4.

Table 12.3 of the ISA Guidelines – Reference 1

Service Conditions	Kinetic Energy Criteria		Equivalent Water Velocity	
	Psi	KPa	ft/sec	m/s
Continuous Service, Single Phase Fluids	70	480	100	30
Cavitating and Multi-phase Fluid Outlet	40	275	75	23
Vibration Sensitive System	11	75	40	12

2. **Question:** What is the basis of the criterion of 4.8 Bar (70 psi) for the valve trim exit kinetic energy?

Response: A. Similitude

The trim Exit Kinetic Energy criterion was selected as a means of expanding the criteria, used for liquids to other fluids and to account for the lower density in gas applications[1]. The velocity criterion had been used for many years in defining successful control valves in critical and severe service applications. The 4.8 Bar (70 psi) criterion is based on water traveling at 30 m/s (100 ft/s), which was the criterion for trim exit used in many valves and for many years by CCI. Thus; $\rho V^2/2g$, is nearly equal to 4.8 Bar (70 psi) when the velocity is 30 m/s and the density (water) is 1000 kg/m^3 (62.4 lb/ft^3).

The formula, $\rho V^2/2g$, is frequently referred to as the velocity head, it is also the dynamic pressure of the fluid traveling at velocity, V, and it is the volumetric kinetic energy of the fluid (kinetic energy density). Thus the kinetic energy is a strong representative expression of the force driven by the pressure difference causing the expansion of the fluid through the valve. It incorporates the influence of density and *amplifies the destructive influence of the fluid velocity*. This dynamic relationship allows extrapolation to other applications with the use of sound engineering principles. The dynamic similarity has been proven successfully with over 20 years of experience in using this relationship. The specific measurement results noted in the 1997 ASME Paper "Fluid Kinetic Energy as a Selection Criteria for Control Valves," Reference 5, provides further support of the dynamic similarity as a means of assuring a successful valve applications. A valve application that can provide excellent process control and a long valve life with minimum operation costs.

An airplane cruising at different altitudes shows a common engineering example of the similitude in the use of the kinetic energy expression. A plane's velocity increases as the density decreases with altitude while maintaining essentially the same dynamic pressure forces, lift, on the wings. As the density decreases with height more velocity is needed to provide the equivalent lift on the wing surface and to hold the plane at a constant height.

[1] For very high pressure gases the density can exceed 320 kgs/m^3 (20 lb/ft^3) more than 1/3 that of many liquids.

B. Industry

A significance reference to the use of the kinetic energy expression is made in the 1973 ISA paper, "Smoothness Affects Noise Generation in Valve Manifolds – Fact or Folklore?" by J. G. Seebold, Reference 6. The principle was also presented in a *Hydrocarbon Processing*, article titled "Reduce Noise in Process Piping," by J. G. Seebold, in 1982, Reference 7. James Seebold has been a fluids flow expert for many years at Chevron Corporation in Richmond, California and was actively involved as an officer in the Institute of Noise Control Engineering. A quote from his publications is:

> As far as flow itself is concerned, noise generation is related to the dynamic pressure. This determines the turbulence intensity and hence the fluctuation pressure levels in the turbulent boundary layer. A thumb rule is that as long as the velocity (in feet per second) does not exceed about 100 times the square root of the specific volume (in cubic feet per pound) for gases and two-phase flow, and 30 feet per second for liquids, no noise problems should result. Standard piping practice rarely exceeds these velocities.

The rule noted by Mr. Seebold works out to a kinetic energy of 0.076 bar (1.1 psi). For 10 m/s (30 ft/s) liquid velocities, velocity head is about 0.43 bar (6.3 psi). This is much more conservative than 2.75 to 4.8 bar suggested by the ISA Guide. However, it is applied to the piping, not a ruggedly designed valve. It supports the use of a density and velocity relationship to evaluate a fluid system for acceptability.

The American Petroleum Institute Recommended Practice 14E, Offshore Production Platform Piping Systems, Reference 8, uses the kinetic energy density as a design criterion. The form of the equation is:

$$V_e = \frac{c}{\sqrt{pm}}$$

where:
V_e = fluid erosion velocity, ft/s
C = empirical constant
pm = gas/liquid mixture density at flowing pressure and temperature.

Table 2, Kinetic Energy Density, API RP 14E comparisons

Application	c	$\rho V^2/2g$
Solids Free Continuous Service	100	0.075 bar (1.1 psi)
Solids Free, Corrosion Controlled, Intermittent Service	250	0.046 bar (6.7 psi)
CCI valve criterion and equivalent value of ‘c’	805	4.8 bar (70 psi)

In this expression c2 is equal to the density times the velocity squared. Values of ‘c’ presented in the recommended practice and the equivalent value of kinetic energy density are shown in Table 2.

As noted from Table 2, the API Recommended Practice values of kinetic energy density are quite conservative when compared to the valve criterion. This again reflects the more rugged construction associated with the valve versus the piping systems.

3. **Question:** What is the basis for the velocity criteria used in the trim exit kinetic energy?

Response: Many valve companies have had internal limits on fluid velocity that they have used for design purposes, however they were treated as trade secrets or internal design limits and were not published. The velocities used were at varying locations in the valves. Some companies did publish the limits in their valve literature, specifically literature in the past by ABB Introl and Neles have shown velocity limits for the valve inlet and/or outlet. These internal industry velocity limits and design criteria were never organized and published. A summary of what is available is included in the ASME Paper “Fluid Kinetic Energy as a Selection Criteria for Control Valves,” Reference 5. A couple of paragraphs from the ASME paper are repeated here:

> Driskell[2] (1983) in his chapter titled ‘Velocity, Vibration, and Noise‘ discusses the reasons why velocity should be controlled. Excessive velocity causes all of the destructive effects that result in a poor valve application. He notes that velocity induced vibration and noise are ‘...a blessing in disguise in that they are a warning of impending failure.‘ Driskell does not discuss where in the valve the velocity needs to be controlled. Unfortunately, when velocity guidelines have been translated to control valve selection they have been interpreted as the velocity exiting the valve body. By the time the fluid is ready to exit the valve body, the influence of ‘high energy‘ has already been imprinted into the fluid stream. For example, the fluid velocity exiting the trim may have created high velocity, erosive jets, and areas of low pressure with resulting flashing and cavitation damage and noisy shock waves. Velocities should be controlled at the trim outlet, not the valve outlet.

> The valve industry has in some cases defined velocity through the trim as a design guideline. These are presented in Ho (1995), Kowalski, et al. (1996), Laing, et al. (1995), Miller (1993, 1996), Stratton and Minoofar (1995) and are used as a basis for the presentation of the criteria discussed in this paper. Schafbush (1993) argues for emphasis on the driving force, pressure drop, instead of the results of the driving force (velocity and kinetic energy) as the selection criteria. Just looking at the pressure drop or fluid velocity at the trim exit ignores the density of the fluid, which is an important parameter in accessing potential problems. A guideline based on the kinetic energy exiting the valve trim involves the driving force, pressure drop, the resultant velocity and the fluid density. Many years of experience in applying this criterion have indicated it is a reliable indicator that is not overly conservative and is applicable to all valve designs.

There have been a number of publications of guidelines regarding pipeline velocities for liquids and gases. Generally these are in handbooks in the fluid transport and power industry. These velocities are much lower than would be allowed in a valve trim because the valve is much more rugged than a pipe suspended between widely spaced supports.

There have also been three valve industry standards that limit the applicability of the standard to velocities that do not exceed a stated value. These are:

> AWWA C 504, which is for rubber lined butterfly valves and provides a limit of applicability of 5 m/s (16 ft/s) The other two are earlier versions of the ISA SP 75.01.01 and IEC 60534-8-3 noise prediction standards that limit their applicability to Mach numbers less than 0.3 and 0.2 for conventional designs and tortuous trim designs, respectively. Mach number is a dimensionless fluid velocity.

From interviews with a number of experienced experts in the fluid control industry an anecdotal input results regarding the use of fluid trim velocity as a design criteria other than that published in the valve literature noted. An interesting input from this interviewing process was that the 23 m/s (75 ft/s) velocity as a cavitation limit originated with the invention of the steam powered ship in the 1800s. At that time it was observed that the tip speed of the propellers on these new inventions had to be

[2] The book by Les Driskell noted above is titled; *Control-Valve Selection and Sizing, Reference* 9.

maintained below 23 m/s or the props would be consumed by cavitation. (Note that 23 m/s in water correspond to 2.75 bar (40-psi) kinetic energy, the cavitation limit presented in the ISA Practical Guide.)

The requirements for not exceeding 75 feet per second were used for many years in US government specifications and eventually got passed down to the aerospace industry in specifications from the government for valves. Richard Self, the founder of CCI and the inventor of the DRAG® valve (1967) worked for many years in the aerospace program and brought that velocity control experience to the control valve industry. Although Dick Self published a number of papers on the DRAG® concept he never revealed the design criteria that were used because he considered it a trade secret. The velocity control concept has been refined over the years to include the density of the fluid via the kinetic energy limit approach and to allow higher energy levels for non-cavitating fluid situations.

Another common example of velocity is the common water faucet. The velocities seen through the vena contracta in common faucets for a municipal water supply at 4.14 bar (60 psi) are approximately 30 m/s (100 ft/s). While the faucet can be heard to audibly cavitate, most faucets will last for many years. This is due to the low energy, entrained gas and the small size of the fluid stream.

4. **Question:** Can the kinetic energy criteria be made non-dimensional?

Response: Maybe, however this is not readily apparent. If the pressure drop across the valve is used as a non-dimensional factor then the ratio of the velocity head to the pressure drop is basically a loss coefficient for the geometry. That is;

$$(\rho V^2/2g)/\Delta P$$

The loss coefficient is not a good measure of whether a valve design is right for the application being considered. A variety of trims with different loss coefficients could be used in the valve but as experience has indicated some are very destructive and others may only do part of the pressure letdown with borderline acceptability.

Some valve designers have suggested that the ΔP should be used as the dominant indicator of whether a valve design is best suited for the application. The question is which pressure drop? The most indicative is the pressure drop across the valve orifice or last stage in the case of multi-stage trim designs. If the orifice pressure drop instead of the valve pressure drop is used then any debate tends to become quite academic as to whether the velocity is important or the pressure drop, since it is the pressure drop that creates the velocity. However, using the velocity in its squared relation assigns the emphasis to this variable that is indicative of its potentially destructive influence.

Another factor for making a non-dimensional factor may be to select specific fluid properties. For example, the fluid density at a flowing condition or at a standard condition and the sonic velocity for the fluid could be used. Thus the factor would be:

$$(\rho V^2/2g)/(\rho_s c^2/2g)$$

Where: "ρ_s" is a density at a specific set of conditions and "c" is the sonic velocity for the fluid conditions.

The disadvantage of such a form is that it first discounts the influence of density in considerations of whether a trim exit energy level could create a problem. For liquids the density ratio is essentially one so only the velocity is considered. This may not be too bad because the densities for most liquids tend to fall within a narrow range and velocity is the most dominant variable in destructive influences.

For gases, there is a large change in density as the fluid moves through the valve when large pressure drops occur and experience indicates that the pressure level is as significant as the pressure letdown. So the density to be used in a dimensionless ratio has some uncertainty as to whether it would be meaningful.

If the sonic velocity is used to make the velocity non-dimensional then the factor basically includes the Mach number (squared). The Mach number has not been a very definitive guide in the past because it imposes too conservative a criterion. For example, many specifications and manufacturers use a criterion of not allowing the valve outlet Mach number to exceed 0.3. This generally results in larger valves than necessary and breaks down completely when a very low outlet pressure exists. If the outlet pressure is a vacuum for example the outlet from the valve will almost always be sonic or near sonic and it is impossible to achieve a 0.3 Mach number value. The presence of a sonic velocity at these partial vacuum pressures is not a problem or concern in most applications because of the low fluid density.

The use of the Mach number is a very good indicator of the noise being generated by a valve trim. However, for other damaging influences such as vibration, erosion and cavitation it is almost a non-issue. The desire is to come up with a factor that will fit a wide range of issues that when met there is a high probability of success in the valve application.

Experience was gained in reviewing the data obtained from the 500 valves that have been retrofit with trim that resolves problems with the original installations, Reference 10. This review did not show any consistency that would suggest a means for non-dimensionalizing the criterion. In addition, since the criterion is essentially a constant for all applications it would not be a candidate for non-dimensionalizing as it is not a variable, a necessary requirement for a non-dimensional approach.

5. **Question:** Why are other major manufacturers not using a kinetic energy approach as a criterion for assuring a good control valve application?

Response: The first input is that the kinetic energy criterion has only been published for a short time, although it is approaching 10 years. Also the inertia to change the current application approach is very large. This inertia is increased due to competitive situations between the control valve manufacturer as well as some of our human nature to not trust input that is not fully understood or that was not developed through our own efforts.

A second input is that many of the other manufacturers do meet the criteria in their valve selections. They just are not aware that they do because the calculation is not being made and it certainly has not been used as a criterion in design. Most pre-designed valves are selected out of a catalog with minimum consideration of the application needs. They tend to be selected only on the basis of meeting the capacity requirements and a trade-off made to provide a competitive offering.

If a manufacturer knows of a particularly severe or traditional tough service they will offer a special product. This special product almost always has design features in the trim that meet the kinetic energy criteria published in the ASME/ISA papers referenced. In some cases it may be higher than the criteria and the particular application is considered OK because that valve application always has to be serviced frequently, or it has always been difficult to control with that valve. Routine checks and adherence of the kinetic energy parameter for all valves can head off later problems in the field application.

A manufacturer may not have a multi-stage trim in their portfolio that will support a low energy design criterion and therefore would not be supportive of a change in the application approach.

Many manufacturers have a maximum pressure drop permitted for the different designs, a constraint established many decades ago. Since the pressure drop does not account for pressure level a number of problems such as cavitation, erosion and vibration can occur. The technical paper "Comparison of Pressure Control versus Discharge Energy Control in Cavitation Service," Reference 11 discusses a typical example in which pressure control has failed to provide a good installation.

6. **Question:** How are other valve manufactures responding to the kinetic energy design criterion?

Response: The most injurious comments the valve user hears is a statement that in essence means the user should trust the supplier. This takes the form of:

- We have done this application many times.
- We understand your needs.
- The criteria are only applicable to CCI and its products.
- The criteria are too conservative (and thus costly).
- Just ignore and/or not acknowledge any benefit for the criteria.
- The criteria are not included in any industry standards.
- We can control the location of the cavitation where it does not cause damage.
- We can control the intensity of the cavitation where it does not cause damage.
- We can control pressures to prevent cavitation damage.

In spite of all of these promises, field problems occur frequently. The user is then in a position of working around the problem, continuing with inferior performance or completely replacing the valve. Without a specific trim exit jet design criteria there is no confidence that the suppliers' promises can be kept. The valve users do not get to make the trade-off decisions that consider all of their economic and performance requirements. These decisions are made by the suppliers, which have different priorities.

Another approach is to discount the energy criteria by providing a lot of technical nonsense. This may take the form of detailed finite element analysis that are pretty and look impressive but say nothing about the ability of the criteria to provide a good control valve installation. In some cases, these finite element models are manipulated to make the supplier look good. These finite element models may be used to show differences between the fluid jet peak and average velocities, thus implying a problem with the kinetic energy criteria, which uses average velocities. Using average velocity keeps the criteria simple and avoids the complexity of determining the peak velocity. If peak velocity were used it would simply mean a lower criteria value to compensate for the different between peak and average velocity, about $(7/8)^2$ for a normal turbulent flow field.[3] For valve trims the peak velocity could be as high as 1.5 to 2 times the average velocity.

The ratio of the peak velocity to the average velocity is mainly an academic issue. For use in comparing valve trims the average velocity is most significant. Typical comparisons of average velocity show that many trims that are not using a kinetic energy design criteria have average velocities much higher than even the peak velocity for the DRAG® design. An analogy that is sometimes used by others is that CCI is driving through a crowded town at 150 kilometers/hour in referring to a high peak velocity. Because the flow path through drilled holes is claimed to be smoother, faster velocities are allowed like on a freeway. However what is not said is that the drilled holes discharge onto seating surfaces and the plug. In other words, the other suppliers are speeding at an average of 550 kilometers/hr down a freeway including the exit ramp.

Occasionally the other suppliers will select a convenient definition or provide an assumption that they claim CCI is following and then show that the errant result demonstrates that

[3] The adjustment is calculated for a typical turbulent model of: $v = v_{max}\left(1-\frac{r}{R}\right)^{\frac{1}{7}}$ where v is velocity and r is radius.

the criteria are not good. None of the presumed assumptions we have heard about from the users bears any resemblance to what CCI has said in its publications or that we follow in our practice. The best thing for the user to do is to ask CCI if the assumptions provided are indeed our practice.

The user must understand that the supplier has a different set of priorities and making sure the valve provides a low cost, low maintenance, and good control is not always at the top of the manufacturer's list.

On the other hand, CCI has been very open. Our publications show the criteria, how they are to be interpreted, and numerous successful installations solving field problems, The use of the criteria by the user will provide a means to compare and evaluate a supplier's offering. Reference 12 shows how the calculations can be made by the user. (In spite of all of CCI's publications, some vendors do not know their products well enough to make an accurate calculation of the trim exit kinetic energy. In most cases this is likely because the sales person does not get to their knowledgeable engineer.)

7. **Question:** Why is the trim outlet kinetic energy considered instead of the valve outlet velocity?

Response: The fluid jet exiting the valve body cannot be ignored, but it is secondary to the higher energy in the jets exiting the trim.

In general, the valve outlet velocity is equivalent to the fluid velocity in the outlet piping. Fluid velocity in pipe flow design has been a historically strong criterion going back for more than 70 years. Pipeline velocities are quite low when compared to the fluid velocities that can be handled in the more rugged valve body enclosure. So looking at a fluid velocity exiting the valve that is equal or near the pipeline fluid velocity is misleading, and will not provide the warnings needed at the valve selection stage to assure a successful application.

It is important to look at the valve exit velocities relative to the pipeline velocity. This is because when an expander is used between the valve and the pipe there could be a jet exiting the valve. Depending upon the amount of expansion and the differences in the jet and pipe velocity, there may be a significant audible noise source and/or a pressure recovery wave that would act as a mechanical vibration source for the piping system.

By focusing on the valve outlet trim kinetic energy, one is looking at the source of the highest energy jets and the root cause of most problems encountered in poor valve applications. "Fluid Kinetic Energy Based Limits in the Design of Control Valves and Valve-Related systems," Reference 13, provides a discussion of the link of the energy to common valve problems. These problems range from unstable forces on the closure member, vibration, noise, cavitation and erosion. If the focus is on the valve outlet, the damaging influence has already been created upstream at the trim outlet and that influence carries downstream, in some cases for a very large number of pipe diameters. For example, for acoustic noise there is only about 1 decibel of noise attenuation for every 100 meters of downstream pipe length. (For large ducting, such as the exhaust to a condenser, the noise may attenuate about 1 dBA for every 10 meters.) The trim exit jet will create an entire spectrum of frequency output at different power levels that are capable of exciting the piping system, as well as the stiffer valve trim components.

An example that illustrates the folly of ignoring the trim exit jet energy is that if one focuses on the valve exit it would indicate that a butterfly valve would be as effective as a multi-stage globe valve. If both valves have the same outlet, then they would be judged to be equivalent in terms of their impact on the application. This of course makes no sense and indeed the various valve suppliers do make different valve design decisions, which in effect say that the trim selection is very important. In selecting different trim configurations the vendor is implicitly controlling the trim exit fluid jet energy.

8. **Question:** Why does ISA not endorse the kinetic energy criteria?

Response: ISA has a form letter that they issue when asked stating that the ISA publication *Practical Guides for Measurement and Control – Control Valves*, Reference 1, "provides applications-oriented coverage of final control elements by documenting the unique experiences and methods of individual industry experts… and reflects practical guidance based on his [the author's] experience." As such ISA, and other standards writing organizations, avoid any commercial endorsement that may compromise their independence and integrity. CCI supports the ISA and IEC efforts in writing standards for control valves and has no argument with their position.

The ISA response also indicates that the material in Reference 1 was reviewed by industry experts. Indeed, the material of Chapter 12 that includes the kinetic energy criteria was reviewed by at least three industry experts, all users. To our knowledge there were no reviewers from a valve manufacturer. Since the reviewers were confidential, CCI does not know their names.

Recent history has shown that utilizing valve users as reviewers was a good decision by the editor, Guy Bordon. All that has resulted from the valve manufacturers is a very defensive, closed mined response. These responses have used many trivial and meaningless arguments against the trim exit energy control. Not one manufacturer has taken the challenge of testing the concept in their own business to measure the significance of the criteria applied to their products. The inertia to change seems to be restricting this evaluation.

When CCI initially published the kinetic energy criteria in 1997, Reference 5, our intent was to challenge the industry to try the concept on all control valves so as to aid the users in making sure they end up with a valve that meets their cost and control expectations. CCI is open to modify the criteria if such experience would dictate a change. Unfortunately the industry response has not taken this direction. As a result, CCI has evaluated the concept by scrutinizing all of the valves retrofitted[4] with energy controlled trim on problem valves in the field. This study is published in References 10, 14-16. The titles and location of the publication are listed below. This study reinforced the benefit and integrity of the criteria in assuring a good control valve installation.

- "The Case for a Kinetic Energy Criterion in Control Valves – Part 1," paper ISA05-P133, presented at the ISA EXPO 2005, Chicago, October 25-27, 2005.
- "The Case for a Kinetic Energy Criterion in Control Valves – Part 3," paper presented at the Ninth NRC/ASME Symposium on Valves, Pumps, and Inservice Testing, Washington D.C., July 17-19, 2006.
- "Fluid Jet Energy Criterion Eliminates Control Valve Problems," *Valve Magazine*, vol. 18, no. 2, April 2006.
- "When all else fails – A kinetic energy criterion for control valves via trim retrofit is the final solution," *InTech*, vol. 53, issue 4, April 2006.

9. **Question:** Why are the kinetic energy criteria not in an ISA/IEC Standard?

Response: In light of the negative response by the control valve suppliers, CCI has not yet proposed the kinetic energy criteria be included in an ISA or IEC standard even though we have been encouraged to do so by a number of major users and engineering firms. At this time there is not enough support on the standards committees. The committees are dominated by valve vendors that have not examined their own products to even know what they are supplying to the users. There needs to be more users involved in these committees to counteract the proprietary interest of the valve manufacturers. We therefore wait as the users gain more knowledge and experience in the implementation of the criteria.

The dominance of the suppliers on the standards committees also leads to statements such as, "IEC clarifies that valve trim exit velocity need not be less than 70 psi." CCI would not expect such a statement from the committee but would expect this to be stated by individuals on the committee reflecting their company's position. A committee response would likely take the form of simply stating that the criteria are not included in their current standards.

10. **Question:** When will the ISA Guideline on Control Valves be revised or a new edition issued?

Response: The editor, Guy Bordon, asked ISA in February 2007, of their plans for a revision. He was advised that there were no plans for a revision or a new edition. A review by ISA as a result of his request indicated that ISA had a four year supply of the current edition, which implied that there would be no consideration for a number of years.

Some valve suppliers' sales personnel have said that there is a letter from ISA indicating that a revision was planned. Obviously this is a false statement.

11. **Question:** What is the "Retrofit Experience?"

Response: References 10, 14-16 present the results of a review of *all of the retrofitted valves that CCI has supplied*. A retrofit is a modification of a valve that involves only a change out of the internal trim, the part taking the pressure drop in the valve.

The new trim controls the trim fluid exit energy level to a specified criterion. The body of the original valve installation was used unchanged and new parts provided to interface the new multi-stage, multi-path tortuous path trim. The replacement trim met the criteria of kinetic energy density defined in *ISA Practical Guidelines for Measurement and Control – Control Valves*, Reference 1. The guideline calls for the trim exit kinetic energy density to be held to a value of 4.8 bar (70 psi) as a design criterion to be implemented <u>after</u> all the conventional steps in good control valve design have been followed.

The retrofits took place because the valves were not performing their intended control function and/or were continually being maintained. The database shows that after retrofit and using trim that limits the kinetic energy, a valve application resulted that met or exceeded the user's expectation. The population of retrofitted valves covers a wide range of sizes, pressure classes, design types, applications, and original suppliers.

The study reviewed the many causes for a user to take the difficult step of retrofitting a control valve in the field. The step to retrofit is only taken after many trials to fix a problem valve. The retrofits of almost 500 valves have shown the power of assuring that the design meets a minimum trim exit fluid kinetic energy density criterion.

One of the most significant observations was the very high kinetic energy levels existing in the original valve designs. This energy was available to enforce and amplify any damaging impact of the trim exit jets and to feed the turbulence that negatively impacts the piping system. These high jet energy designs failed repeatedly. The failures were made into successful applications, for a wide range conditions that encompass the entire control valve spectrum. The only change in the retrofitted valve was to reduce the fluid energy level exiting the valve trim to acceptable levels.

[4] A retrofit is a modification of a valve that involves only a change out of the internal trim of the valve. The valve body is not altered so that the only impact of the retrofit is to provide a change to an energy control trim.

12. Question: What if the kinetic energy criteria are ignored?

Response: If the criteria are ignored, the user will risk buying a valve that may not meet the requirements for good control and reliable performance. It will allow the supplier to avoid any measure of risk associated with the installation. It will allow the supplier to provide a low cost valve that meets capacity but may not meet your expectations for good control and low maintenance costs. Providing the lowest cost approach that meets capacity usually means the valve will have the highest trim jet kinetic energies allowed by the supplier (even though the supplier may not know the level or value of the resulting jet kinetic energy).

CCI frequently benefits from installations that have not paid attention to the valve trim exit jet energy. We get a chance to replace or retrofit (when possible) valves that are not performing to expectations.

Conclusion:

The use of kinetic energy, $\rho V^2/2g$, as a means of extrapolating good control valve experience to new applications is sound engineering practice.

Experience gained in the fluid flow industries has helped to establish values for the kinetic energy level that result in good control valve applications.

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