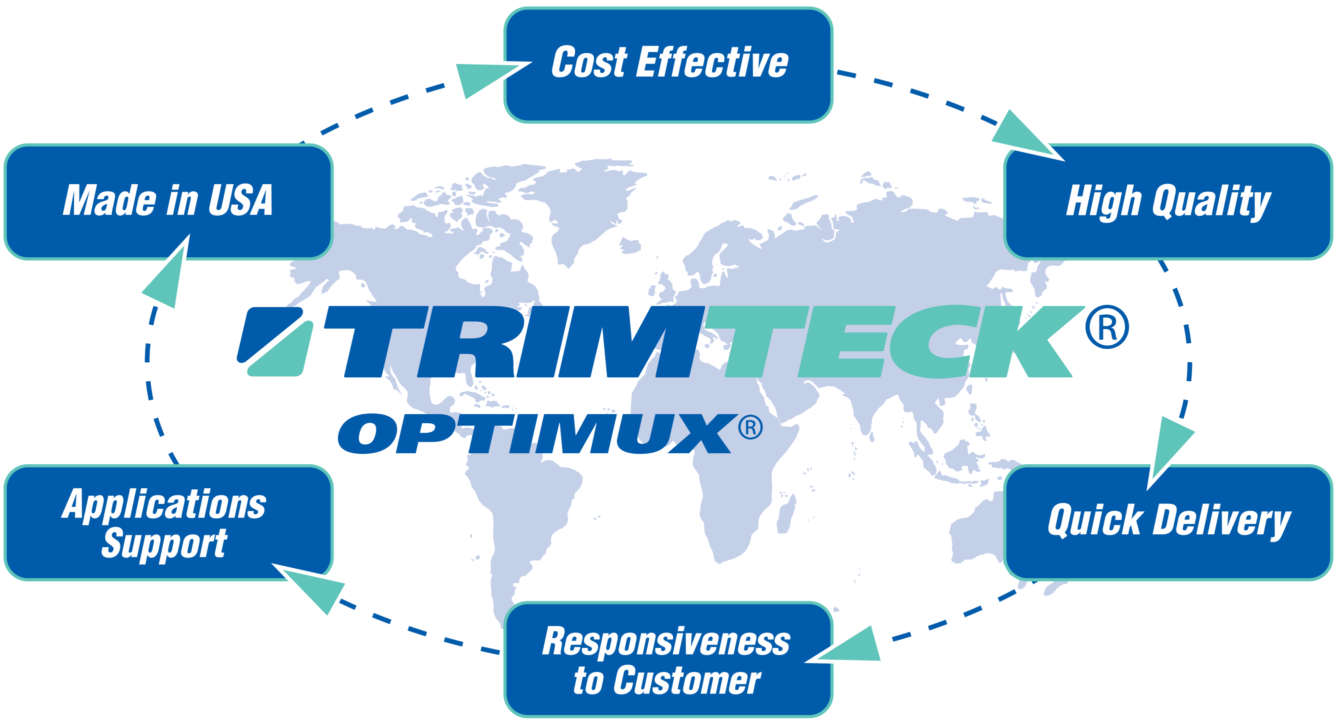
TRIMTECK®
OPTIMUX®

Severe Service
CONTROL VALVE TRIM

Reducing and controlling the effects of **cavitation**, **flashing** and **noise**.

When you partner with Trimteck® you can expect:



About Trimteck®

Trimteck is a family-owned American company with over thirty years of experience in engineering, manufacturing, and marketing flow control solutions and equipment for a variety of industries. Our application engineers and certified representatives are committed to personalized customer service and have an extensive line of products and technologies to draw upon when designing and specifying a solution.

With a comprehensive line of Optimux control valves – and an array of actuators, positioners, severe service trims, and other accessories – our engineers and representatives can solve the most complex flow control problems quickly and economically. Moreover, our organizational focus on implementing highly efficient sourcing, engineering, manufacturing, assembly, and distribution processes enables us to guarantee world-class quality, competitive pricing, and rapid delivery to anywhere in the world.

Welcome to Trimteck.

Introduction to Noise, Cavitation, and Flashing

Cavitation, flashing, and noise in control valves are a concern for plant stakeholders, such as operators, maintenance personnel, and owners, because they can be the source of decreased utility and profitability. Cavitating or noisy valves can cause damage to pipelines and other equipment, increasing the likelihood of unplanned downtime.

Trimteck designs, engineers, and manufactures an array of control valve trims that control cavitation and abate noise in all manner of applications. This document aims to explain the source of cavitation and noise, its effects on various applications and industries, and Trimteck approach to ameliorating or altogether solving such problems.

The basic ***Trimteck*** severe service trim designs described herein are custom-engineered and adapted depending on the unique challenges of the industry and application.

Oil & Gas, Refining, and Petrochemicals

Media

Crude oil, Refined Hydrocarbons, Water, Multi-Phase Fluids, Natural Gas, Corrosive Processed Chemicals

Challenges for Controlling Cavitation & Noise

Particulates in suspension, Process variability, Broad range of valve types and sizes

Power

Media

Steam, Saturated Steam, High Pressure Water

Commonly Problematic Applications

Boiler Feedwater, Recirculation, Anti-Surge, Desuperheating

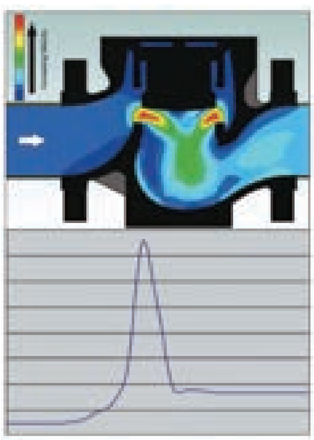
Other Industries

Pulp & Paper, Metals & Mining, Chemical, Food & Beverage, Aerospace & Defense

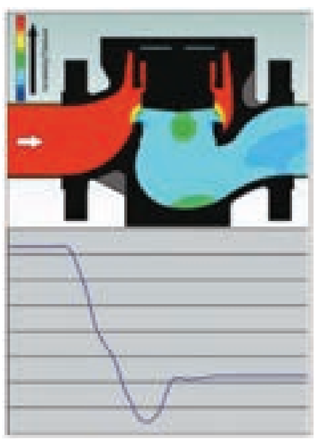
Cavitation, Flashing, and Noise Explained

Cavitation and flashing in control valves occur only with liquid media, whereas noise can be associated with both liquid and gaseous media. In both cases the principal variables in question are fluid velocity and pressure drop.

Across a valve, choked flow is a phenomenon that begins to occur at the point at which flow ceases to increase as the pressure differential is increased. That is, there is a maximum flow that can be achieved through any given valve, and beyond this threshold is where choked flow occurs.



Velocity



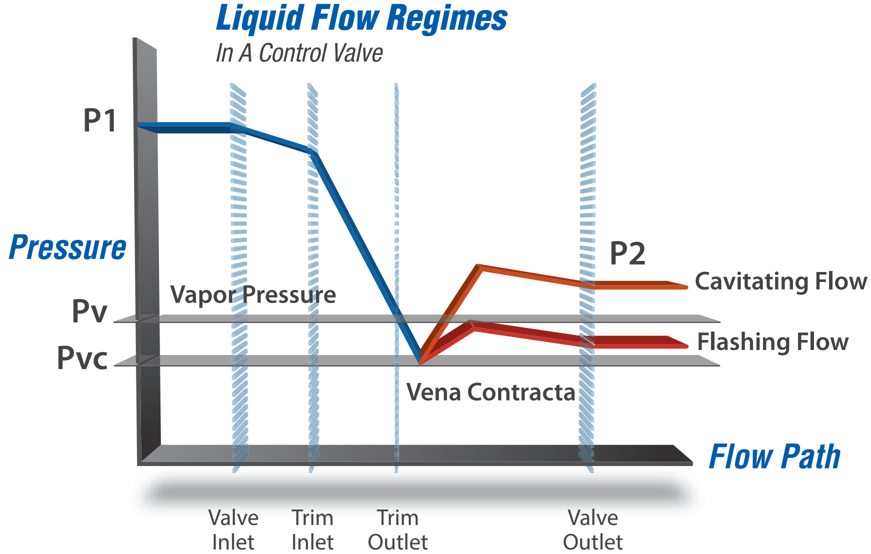
Pressure

Pressure drop occurs through a valve because as velocity increases to its maximum through the flow restriction, pressure decreases to its minimum. As velocity normalizes over distance downstream, pressure recovers as well but not to the level it was at upstream of the restriction. The point at which pressure is at its minimum and velocity is at its maximum is called the vena contracta. In liquids, at this point the local pressure may drop to or below the liquid's vapor pressure, forming vapor cavities, or bubbles in the fluid. The fluid then essentially becomes multi-phase, or a combination of liquid and gaseous, and the density thereof continues to decrease as more vapor cavities are formed. The fluid reaches its minimum density at choked flow

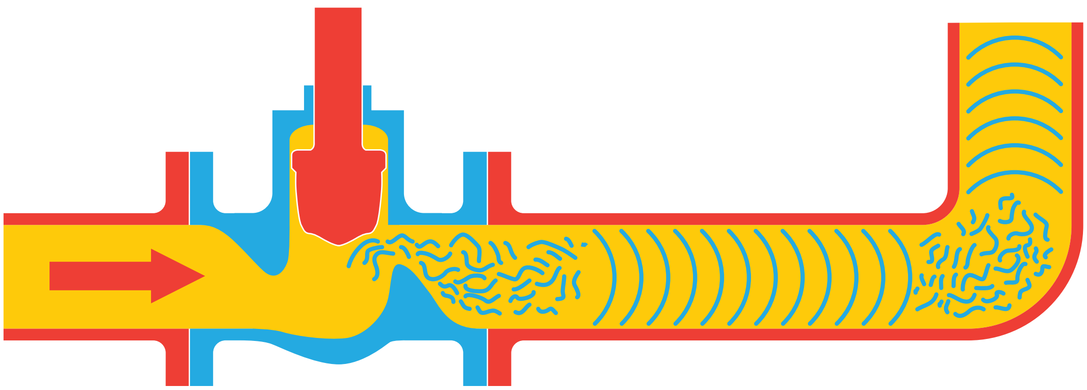
If the liquid pressure downstream of the vena contracta recovers to a point higher than the vapor pressure, the vapor cavities will collapse. This is called cavitation. If the liquid pressure downstream does not recover and remains below the vapor pressure, the vapor cavities do not collapse and cause further damage. This is called flashing.

Liquid Flow Regimes

In A Control Valve



Both cavitation and flashing tend to cause hydrodynamic noise in a valve, but aerodynamic noise in gas or vapor service is typically what constitutes a noisy problem valve. Aerodynamic noise in valves is caused by fluid turbulence that typically originates within the valve body. First, fluid turbulence, and thus noise, can occur within the valve trim as velocity increases and pressure decreases. Second, it can occur in the region between the valve trim and the body wall as fluid impinges on itself. Lastly, another noise source can be the combination of the turbulence at the valve outlet and the vibration of the downstream pipe.



Throttling across a control valve generates high turbulence.

Factors Affecting Cavitation and Noise

Cavitation and noise do not always cause damage, but when they do they depend largely on the following factors:

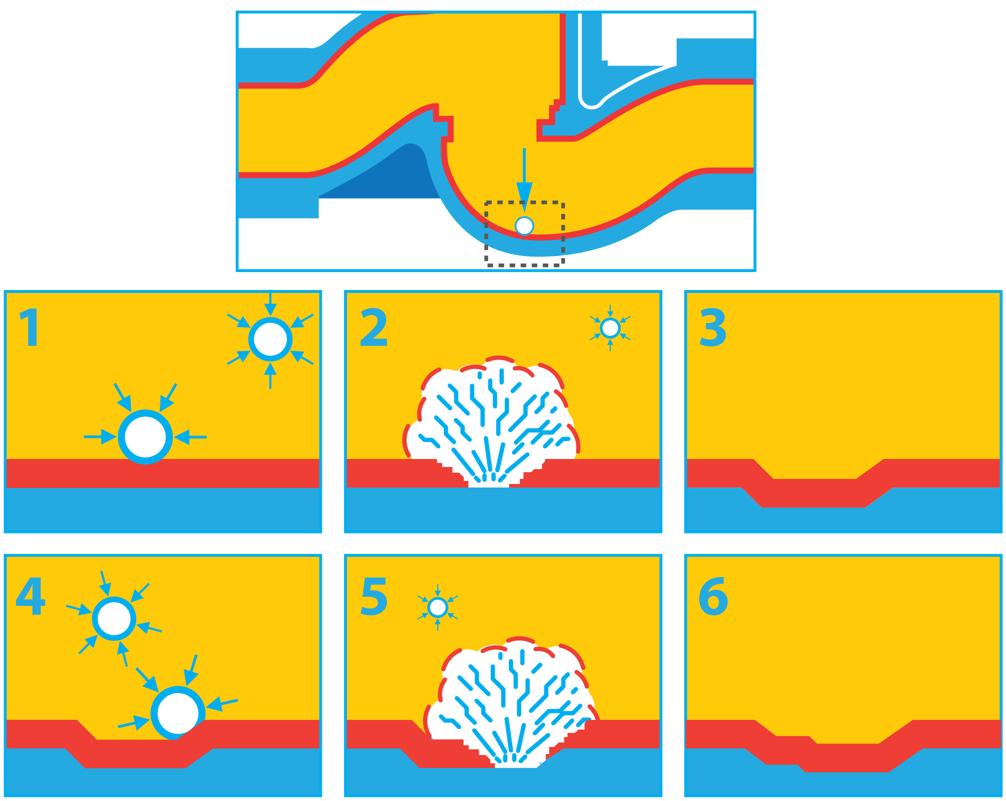
- ***Pressure Drop:*** the higher the pressure the drop, the greater the chance of damage as a result of noise and cavitation.
- ***Time of Exposure:*** the longer cavitation or noise occurs in an area, the more likely it is to result in damage
- ***Materials:*** hardened materials reduce damage and extend the life of the trim and/or valve. For noise, thicker and larger diameter pipelines and valve bodies help in abatement.
- ***Flow Rate:*** both cavitation and noise tend to increase with increasing flow rates.
- ***Valve and Trim Design:*** Trimteck produces anti-cavitation and anti-noise trim to counteract the effects of cavitation and abate noise.
- ***Seat Leakage:*** if leakage occurs through the seat of the valve while it is closed, the fluid escapes from a high-pressure area to a low-pressure area, which can exacerbate cavitation and noise. Trimteck's Optimux® control valves achieve ANSI Class V metal-to-metal seat leakage, which minimizes seat leakage.
- ***Fluid:*** behavior, specific gravity, and viscosity of fluid need to be considered when selecting Trimteck valves and trim.

Cavitation Damage

Cavitation damage is a form of hyper erosion that can destroy both piping and control valves, which can result in unacceptable process failures. The vapor bubbles created as a result of a pressure drop will implode – nucleate, grow, collapse, and rebound – as the vapor turns back to liquid. This implosion inflicts damage in the form of small pits in the metal, which cumulatively begin to wear away seating surfaces or drill holes through pressure vessel walls.

To ensure that valve damage has been caused by cavitation and not corrosion, determining a precise location is important. This is due to the fact that corrosion damage can often look very similar to cavitation damage. However, cavitation damage is almost always located downstream of the seating areas and can sometimes be found further down the line in the piping, whereas corrosion damage tends to form in narrow gaps and crevices.

Control Valve Plug Damaged by Cavitation



Imploding Vapor Bubbles Damage Control Valve Body

Trimteck's Approach

to Solving Cavitation and Noise-Related Severe Service Problems

Severe service applications vary in degree of severity, so ***Trimteck*** offers its customers appropriate, timely, cost-effective products to enhance performance while driving down operating costs. Our rationale is simple: invest in a reasonably-priced custom-engineered solution and enjoy extended performance combined with a dramatic reduction in operation and maintenance costs caused by failures and untimely shutdowns

When operating conditions in a process loop are fixed, a control valve may be called upon to perform under unavoidable cavitating conditions. Of course, a single anti-cavitation or noise abatement design is not sufficient for the wide variety of applications that exist across a multitude of industries. Therefore, ***Trimteck*** employs a wealth of experience and knowledge of severe services and the effects of valve size, type, trim design, geometry, and materials when designing a solution. We use differing methods and technologies for solving cavitation and noise issues that involve one or more of the following:

- Selection of ***appropriate materials,*** some of which are more resistant to cavitation than others
- Introduction of ***multi-stage pressure-reducing trims,*** which create a torturous path to reduce velocity, pressure, and energy levels
- Utilization of ***low recovery trim packages,*** which break down the mass flow into a multiplicity of small flow streams
- ***Optimization of flow direction*** to take further advantage of the design mechanics

Trimteck Severe Service Trim Cage

Precision CNC machining of ST-2 Trim

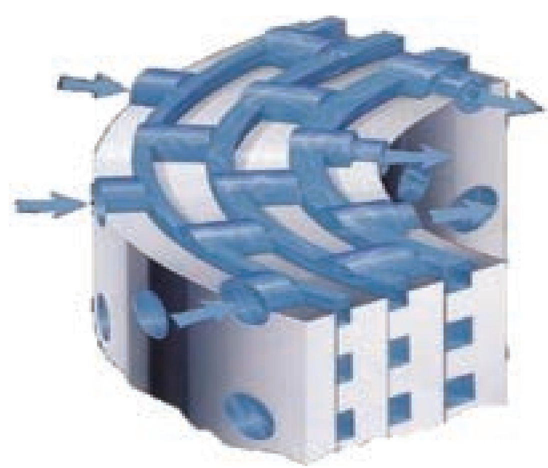
Trimteck's Approach
(continued)

In cases of minimal or incipient cavitation, material selection can be a sufficient method of control. Typically, valve body materials are relatively soft. As a general rule, as the chrome and molybdenum content increase, so does the material's resistance to cavitation. High-grade stainless steels, then, are much more resistant to cavitation than carbon steels. However, often times in order to further increase hardness and toughness of materials, ***Trimteck*** uses its proprietary CVD-5B hardening process, which significantly improves the cavitation resistance of stainless and carbon steels. This treatment alone is often sufficient for low pressure cavitation.

When pressures are relatively low and some cavitation control is required, a single stage "mutual impingement" trim that directs streams of cavitation bubbles into each other is often sufficient to reduce the effects of cavitation. This method essentially involves controlling or dissipating the energy of the imploding vapor bubbles by isolating them away from valve or trim surfaces with the use of low recovery trim packages.

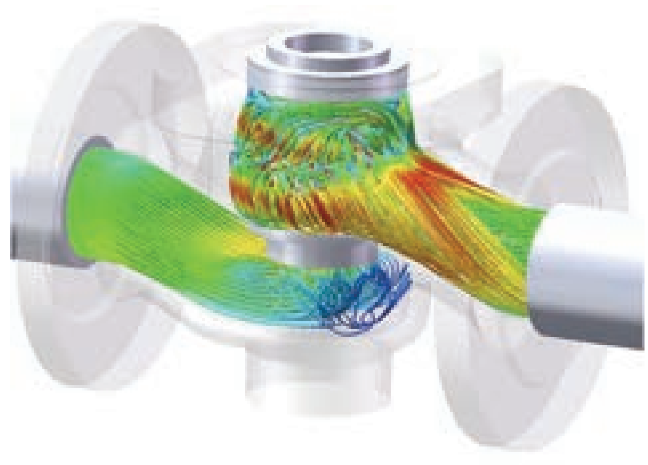
However, in cases of more severe cavitation, the ideal solution to more severe cavitation is to reduce the pressure from inlet to outlet gradually, thus avoiding the pressure drop at the vena contracta altogether. It can be eliminated entirely by not allowing the pressure to fall below the liquid's vapor pressure, which eliminates the formation of bubbles and their subsequent damaging collapse. ***Trimteck*** achieves this with single and multi-stage pressure-reducing trim.

To learn more about CVD-5B, see page 16.



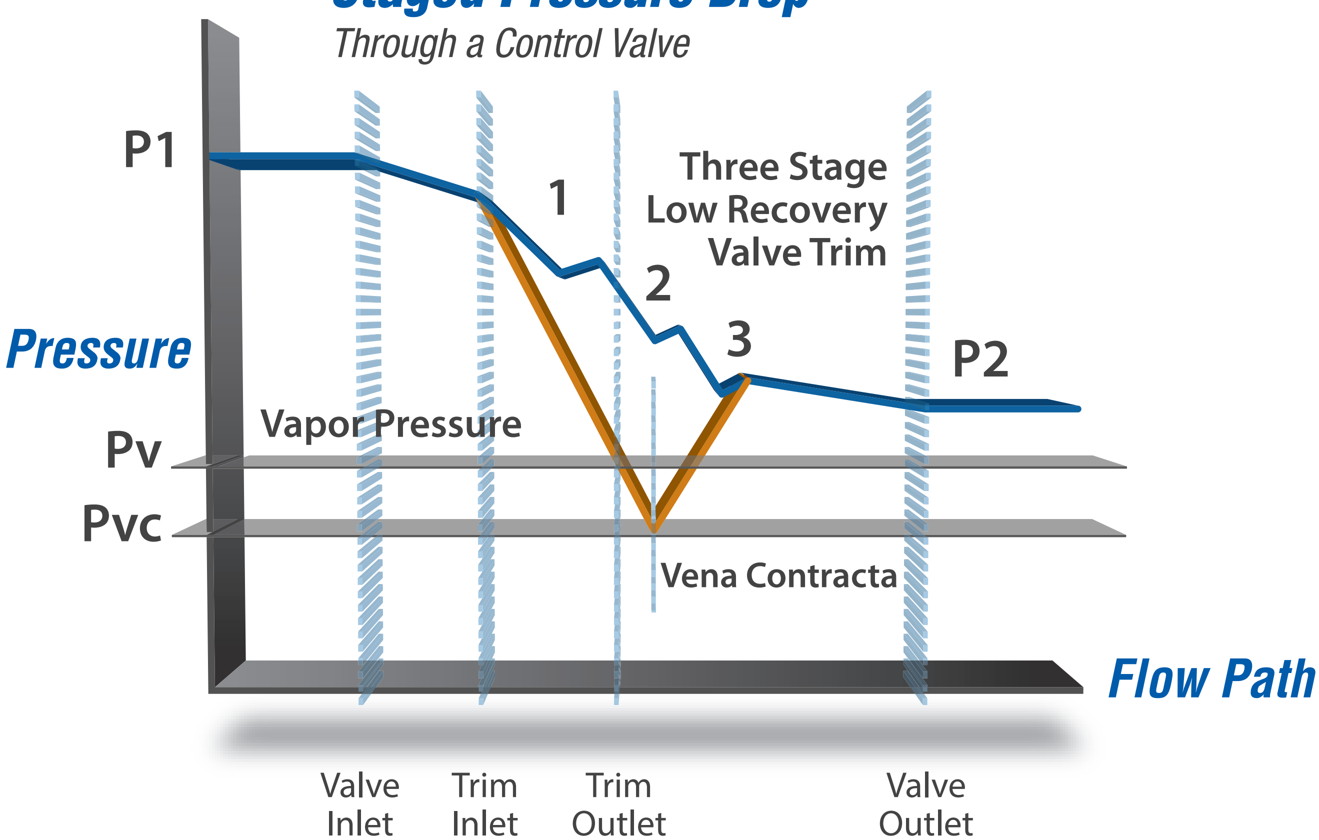
Trimteck ST-2 Four Stage Pressure Reducing Trim

Similarly, for noisy applications, the focus of the solution to the unwanted noise originating in the valve is through use low-recovery trim packages that break up the flow into smaller flows, as well as multi-stage pressure reducing cylinders.



Staged Pressure Drop

Through a Control Valve



Sigma σ: The Cavitation Index

In the past there have been a variety of indices used to correlate performance data to improve design of process equipment. The most widely-accepted and precise cavitation index used to quantify cavitation in control valves is Sigma (σ). Simply put, Sigma is the ratio of the potential for resisting formation of vapor cavities to the potential for causing formation of vapor cavities.

Sigma is defined below:

$$\sigma = \frac{(P1-PV)}{(P1-P2)}$$

Where:

P1 = Upstream pressure (psia)

P2 = Downstream pressure (psia)

PV = Vapor pressure of the liquid at flowing temperature

Acceptable operating Sigmas for eliminating or reducing cavitation and its associated damage have been established over time through laboratory and field tests.

The typical ***Optimux® OpGL*** globe valve's operating conditions fall into the following categories:

$\sigma \geq 2.0$	No cavitation
$1.7 < \sigma < 2.0$	Hardened trim provides sufficient protection
$1.5 < \sigma < 1.7$	Some cavitation, single-stage trim may work
$1.0 < \sigma < 1.5$	Potential for severe cavitation, multi-stage pressure drop trim required
$\sigma < 1.0$	Flashing

Of course, additional factors need to be considered when sizing a valve and selecting trim for an actual application. In doing so, the various calculated and tested Sigmas can be compared to the above general categories to show how they are used.

We also note that the type of valve used in a given application does make a difference in the possible level of resistance to cavitation. The table below lays out some sigma limits for various types of ***Trimteck*** control valves.

Common Valve Recovery Coefficients

Valve/Trim Type	Flow Direction	Trim Size	F_L	Fi	σ choked*	σ incipient* damage
OpDX High Performance Butterfly	90° Open	Full	0.56	0.49	3.17	4.16
OpVEE V-Notch Ball	90° Open	Full	0.60	0.54	2.78	3.43
OpGL Globe	Over	Full	0.85	0.76	1.38	1.73
	Under	All	0.90	0.81	1.23	1.52
ST-1 Single-Stage	Over Seat	All	0.92	0.85	1.18	1.20
ST-2 Multi-Stage	Over Seat	All	~1.0**	***	**	1.20-1.001

** Pressure and size scale factors not included in these calculations*
*** Choking will not occur if properly applied*
**** Does not apply to valves with ST-2 multi-stage trim*

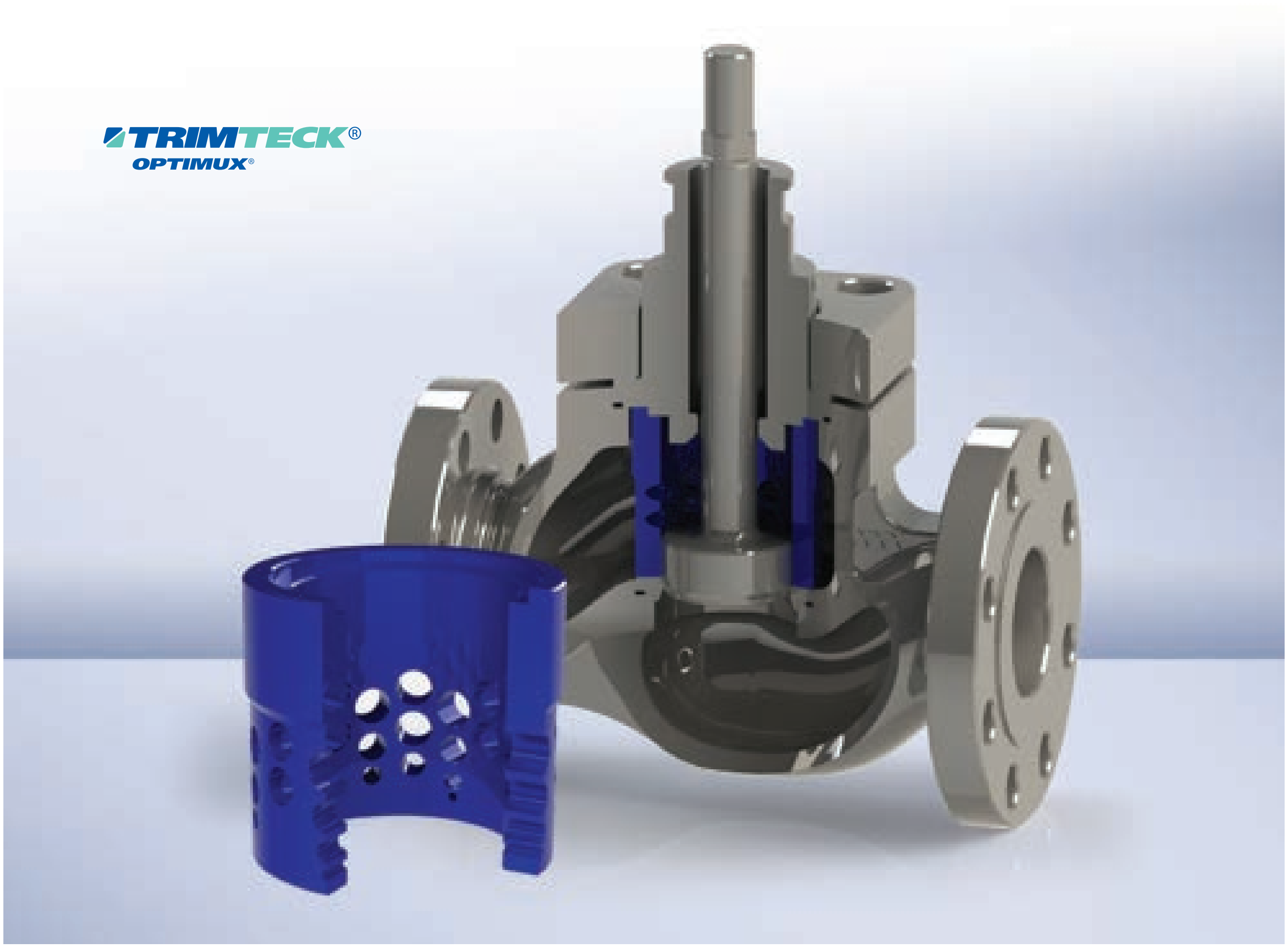
Trimteck® ST-1

Single Stage Anti-Cavitation Trim

ST-1 trim is a cost-effective single-stage trim that minimizes cavitation damage to valve and piping by diverting the location and controlling the concentration of imploding vapor bubbles to an area away from metal parts. The ST-1 trim works with diametrically opposed drilled, stepped holes that force vapor jets to impinge on each other in a column at the center of the cage rather than erode the valve body or trim.

As with all other ***Trimteck-Optimux®*** control valves and products, ST-1 trim is designed with maintenance, reliability, performance, and high interchangeability of parts in mind.

Type	ST-1 Single Stage Trim for Mild Cavitation
Base Valve	Optimux OpGL Globe or Angle Body
Size Range	1" to 24"
CV Range	1.5 to 1,000
Flow Direction	Flow Over
Pressure Stages	1
Features	• Tolerates Sigma as low as 1.2 • Can be characterized • Cost-effective



Trimteck® ST-2

Multi-Stage Anti-Cavitation Trim

ST-2 Multi-Stage trim not only eliminates cavitation damage, but it often prevents cavitation from occurring altogether. By reducing pressure through a series of restrictive channels and expansion areas, it prevents vapor bubbles from forming and minimizes hydrodynamic noise. The ST-2 Multi-Stage cartridge consists of concentric cylinders of drilled holes and grooved channels; the expansion and contraction of the fluid from channels through holes and back into channels create a series of pressure drops that eliminate cavitation in most applications, and reduces cavitation damage others.

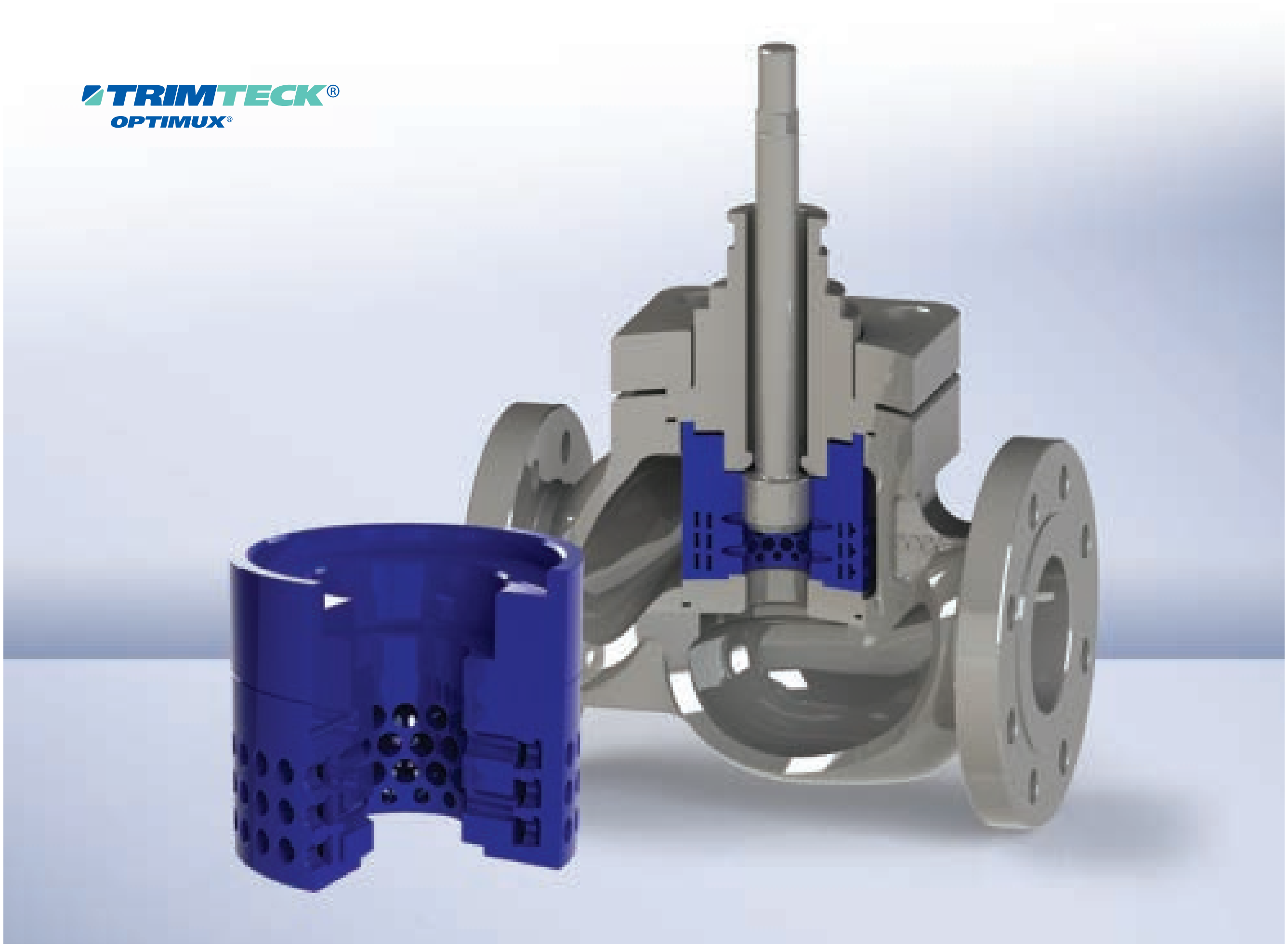
Type	ST-2 Multi Stage Trim for Cavitation
Base Valve	Optimux OpGL Globe or Angle Body
Size Range	1" to 32"
CV Range	6 to 720
Flow Direction	Flow Over
Pressure Stages	2 to 6
Features	• Tolerates Sigma as low as 1.001 • Eliminates mild to moderate cavitation • Controls effects of heavy cavitation • Custom-engineered for optimization and characterization of flow according to application requirements – including dirty service

Trimteck® ST-3

Noise Attenuation Trim

ST-3 Noise Attenuation trim works to reduce control valve noise in a broad spectrum of gas applications. ST-3 trim has two variants: the first is a one or two-stage design that reduces noise levels up to 15 dBA, the second is a multi-stage design for more extreme noise reduction up to 30 dBA. ST-3 works by controlling both pressure and velocity of the gas through the valve, thereby reducing turbulence, which is the culprit of all aerodynamic control valve noise. Multi-stage ST-3 reduces pressure with a concentric cylinder design similar to the ST-2 anti cavitation trim.

Type	ST-3 Noise Attenuation Trim
Base Valve	Optimux OpGL Globe or Angle Body
Size Range	1” to 32”
CV Range	1 to 3220
Flow Direction	Flow Under
Pressure Stages	1 to 6
Features	• Effective attenuation of up to 30 dBA of noise • 1 or 2 stage cartridges fit a standard OpGL without modification



Trimteck® Downstream Devices for Noise Attenuation
ST-3D and ST-3P

When ST-3 or ST-4 in-valve noise attenuation trim is insufficient to reduce noise to acceptable levels, Trimteck offers economical downstream devices for additional attenuation: ST-3D Diffusers and ST-3P Diffuser Plates, both capable of noise reductions of up to 25dBA. For more extreme reductions, Trimteck also offers in-line silencers with the capacity to reduce noise levels by more than 30dBA.

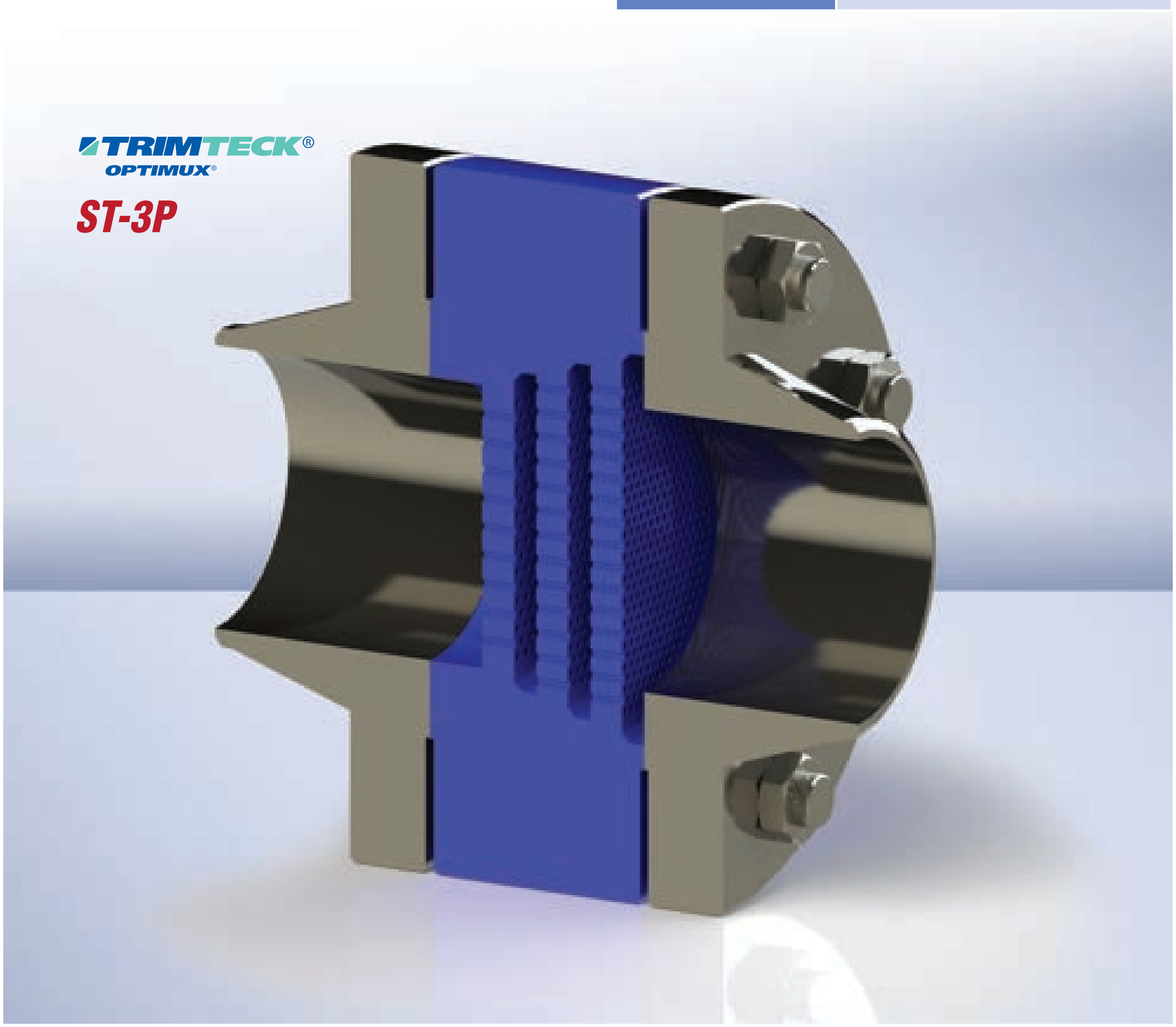
Type	ST-3D Diffuser
Style	Wafer, Outlet Head, Open Shell
Size Range	1” to 42”
ANSI Rating	150, 300, 600, 900, 1500, 2500
Flow Direction	One Way
Pressure Stages	1
Features	• Length and Number of holes are custom-designed for specific applications • Commonly manufactured from carbon and stainless steels, but available in a variety of other materials

Downstream Devices for Noise Attenuation (continued)

Any of these solutions can be used in series with Trimteck's Optimux OpGL Globe Control Valves fitted with ST-3 or ST-4 noise abatement trims to cost-effectively reduce noise levels and provide backpressure in many applications.

ST-3D Diffuser in 316SS

Type	ST-3P Plate
Style	Wafer, Flanged
Size Range	2" to 32"
ANSI Rating	150, 300, 600, 900, 1500, 2500
Flow Direction	One Way
Pressure Stages	1-4
Features	• Stages minimize turbulence and absorb pressure drop • Commonly manufactured from carbon and stainless steels, but available in a variety of other materials



Trimteck® ST-4

Stacked Disc Anti-Cavitation & Noise Abatement Trim

ST-4 Stacked Disc trim is a powerful solution designed to tackle the most severe pressure drops while reducing sound levels and eliminating the effects of cavitation. It can be used in liquid, gas, or multi-phase service. The ST-4 design consists of individual discs machined with progressively deeper concentric grooves machined and stacked to create a compact cylinder. The cylinder is then clamped into the body cavity of an OpGL globe valve and doubles as a seat retainer. Flow in this case is under the plug and as the fluid travels from the interior of the cylinder through the jagged grooves it is forced to make a series of 45o dives and ascents. Simultaneously the space between the grooves grows as you move from the center of the cylinder outward, allowing for expansion and thus reducing pressure in stages.

Type	ST-4 Stacked Disc Trim
Base Valve	Optimux OpGL Globe or Angle Body
Size Range	1.5” to 38”
CV Range	4 to 4000
Flow Direction	Flow Under
Pressure Stages	2 to 10
Features	• Tolerates Sigma as low as 1.001 • Eliminates cavitation • Tolerant of dirty services • Noise attenuation up to 30 dBA • Custom-engineered for optimization and characterization of flow according to application requirements

Trimteck® ST-5

Venturi Seat Ring for Flashing Service

No matter how many pressure stages are introduced into a valve, in flashing service the pressure drop will result in the liquid flashing from liquid form to a gaseous form – carrying with it erosive water droplets at high velocity.

Therefore, if flashing is present in a service, then the damaging effects must be controlled by displacing the erosion to non-critical components in the system. One way to do this is with a CVD-5B hardened ST-5 Venturi Seat.

Type	ST-5 Venturi Seat
Base Valve	Optimux OpGL Angle Body
Size Range	1” to 42”
Cv Range	1.5 to 4000
Flow Direction	Flow Over
Pressure Stages	1
Features	• For Sigmas under 1.0 • Displaces flashing downstream • Tolerant of dirty services • Economical and easily replaceable

Trimteck® CVD-5B

Metal Hardening Process

Trimteck is at the forefront of applying innovations in material science to extend the life of its process control equipment. First used in the aerospace industry to harden rocket nozzles on the space shuttle, CVD-5B is a chemical vapor diffusion process using boron wherein a hard wear-resistant metal mesh is fused into the surface of a wide variety of ferrous and non-ferrous materials.

Unlike coatings, during the CVD-5B process, superheated boron atoms are diffused deep into a host surface to form a metal boride layer that permeates evenly up to .015”. Trimteck has harnessed and perfected this advanced technology to, in many cases, effectively extend the life of our valves more than 10 fold.

- **Economical alternative to Tungsten Carbide**
- **Corrosion resistant**
- **Lends extended life to severe service trims**
- **Resists temperatures of up to 1200º F**
- **Reduces coefficient of friction**
- **Not a ceramic, will not crack under duress**

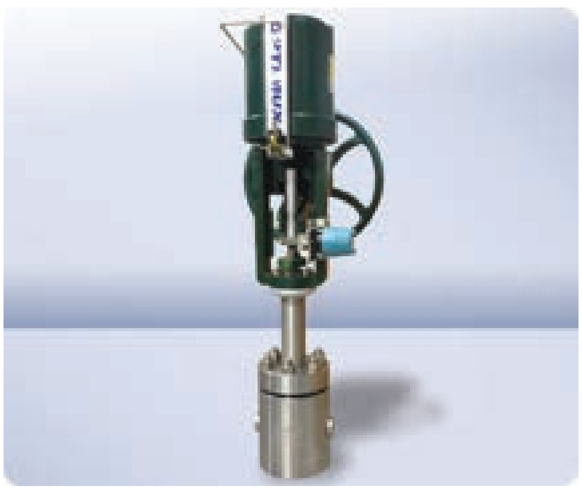
CVD-5B significantly extends the life of Severe Service Trim

Trim Material	Hardness Rockwell C	Impact Strength	Corrosion Resistance	Max Temperature ºF	Max Temperature ºC	Erosion Resistance	Abrasion Resistance
316 Stainless Steel	8	Excellent	Excellent	600	315	Fair	Fair
nº 6 Stellite	44	Excellent	Excellent	1500	815	Good	Good
416 Stainless Steel	40	Good	Fair	800	426	Good	Good
17 – 4 PH H 900	44	Good	Good to Excellent	800	426	Good	Good
440 C Stainless Steel	55-60	Fair	Fair	800	426	Excellent	Excellent
K Monel	32	Good	Good to Excellent	600	315	Fair to Good	Good
Tungsten Carbide	72	Fair	Good on bases Poor on acids	1200	648	Excellent	Excellent
CVD-5B	**72**	**Excellent**	**Good**	**1200**	**648**	**Excellent**	**Excellent**

In addition to CVD-5B, Trimteck provides other common metal hardening processes:

- Tungsten Carbide
- Stellite
- Nickel
- Hard Chrome
- Titanium
- Zirconium

2" CL150 Optimux OpGL ST1 in CF8M



3" CL2500 Optimux Fabricated OpGL-XT ST2 for Cavitating Liquid Service

12" CL600 Optimux OpGL ST3 in WCB for Natural Gas Service

When ordering anti cavitation trim, please specify:

Application Information

1. Process Liquid: state particle size and type of impurities, if any.
2. Specific gravity
3. Temperature and vapor pressure of fluid
4. Critial pressure
5. Rage of flowing inlet pressures
6. Pressure drops
   a. Range of flowing pressure drops
   b. Maximum at shutoff
7. Flow rates
   a. Minimum controlled flow
   b. Normal flow
   c. Maximum flow
8. Required CV
9. Line size and schedule

Severe Service

The information and specifications contained herein are accurate, however they are intended for informational purposes only and should not be used to specify or size process control equipment without the assistance of an experienced Trimteck representative.

Moreover, Trimteck-Optimux products are continuously improved upon and upgraded, therefore information in this document is subject to change without notice.

Trimteck uses the ISA Recommended Practice for evaluating control valve cavitation (ISA-RP75.23-1995) as its basis for calculating potential for cavitation in process control equipment.

Consult your Trimteck representative for specific instructions on installation, operation, troubleshooting, or maintenance of the products depicted in this document.

For more information, visit our website at www.trimteck.com

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