VECTOR™

VELOCITY CONTROL TECHNOLOGY

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DESUPERHEATERS

D SERIES

KOSO

KOSO offers an adequate variety of desuperheating solutions. Most importantly, **KOSO** has the know-how to help select the right solution using software which is based on expert analysis and field experience.

This document is intended to give a broad overview of **KOSO**'s range of standard desuperheaters. Solutions can also be customized to meet unique application requirements where necessary.

Desuperheating

The process of cooling superheated steam by direct injection of water is called desuperheating. This is typically done to meet the conditions required for downstream process(es) when the available steam happens to be at higher temperature and there is also a source for injecting spraywater into it. It is required in many industrial processes where the steam temperature, and/ or quality, is critical for reliable and efficient operation of the system. Such systems are common in power stations, refineries, pulp & paper industry and desalination plants, where a boiler producing superheated steam already exists.

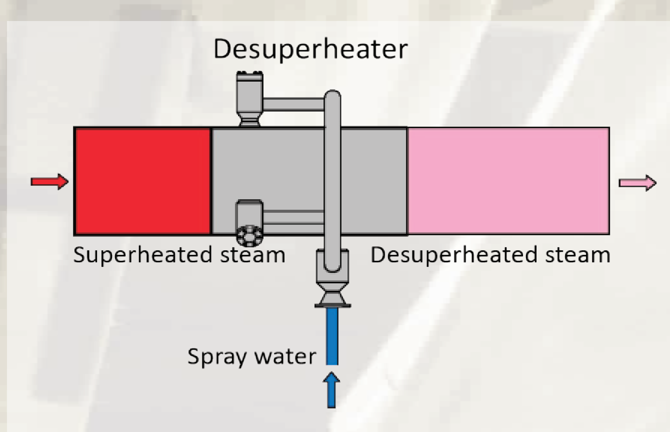


Fig. 1 Simple schematic of a desuperheating process

There are four basic steps:

- Injection of the correct amount of spraywater
- Spray atomization (primary and secondary)
- Spray penetration and pre-evaporation mixing
- Evaporation and mixing

Injection of the correct amount of spraywater flow is the first and most fundamental requirement to correct operation of any desuperheating system. This requires careful, and correct, selection of the spraywater flow control element. This control element, which may be an external control valve, must be capable of providing good control over the entire range of spraywater flow required. Multi-stage pressure drop is necessary in cases of high pressure drop for long-term reliability.

The quantity of cooling water required is determined from heat balance and mass balance principles, which leads to:

$$Q_W = Q_S \times \frac{h_1 - h_2}{h_2 - h_W}$$

Where:

Q_W = Water quantity required in kg/hr

Q_S = Steam flow in kg/hr

h_1 = Enthalpy of inlet Steam in kJ/kg

h_2 = Enthalpy of outlet Steam in kJ/kg

h_W = Enthalpy of spray water in kJ/kg

Atomization

Atomization of the injected spraywater into droplets increases surface area for heat transfer with the surrounding steam. Smaller droplet size is desirable because it means higher surface area of the spraywater and evaporate more easily.

The most significant parameter governing atomization is Weber number, defined as:

$$We = \frac{\rho U^2 d}{\sigma}$$

Where:

ρ = Density of steam in kg/m3

U = Relative velocity of Steam in m/s

d = Droplet diameter in m

σ = Surface tension of water in N/m

Droplets are stable when the Weber number is below the critical value which is generally in the range of 12 - 16. Droplets with higher Weber number continue to break up until they reach a stable size. Primary atomization depends on the spray nozzle design. In spray nozzles using pressure drop.

Secondary atomization (Fig. 2) is another mechanism for break-up of drops. The energy of the surrounding flowing steam provides the force for droplet break-up in such cases.

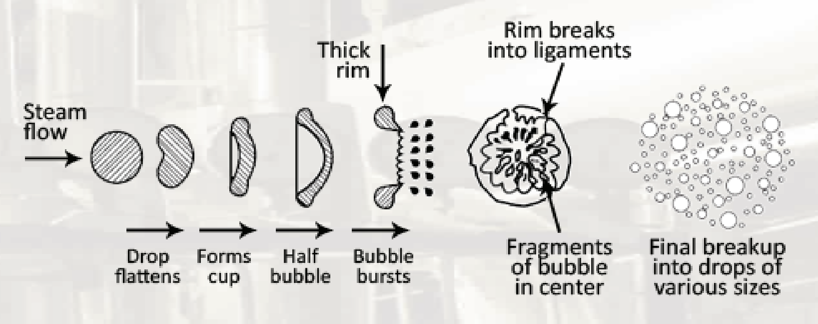
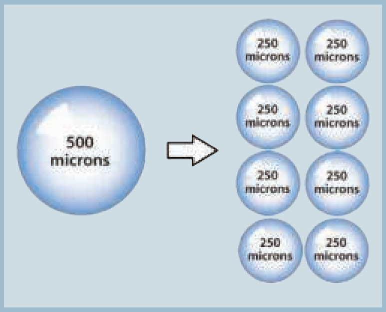


Fig. 2 Secondary breakup of water droplet by interaction with steam

Small droplets are beneficial in desuperheating because they evaporate faster and also stay suspended easily in the steam flow. So, good atomization is a very critical step in desuperheating. **KOSO** uses both primary and secondary atomization principles to achieve small droplet sizes, below 250 μm diameter as a general rule.



Reduction in droplet diameter by a factor of two (2) increases the surface area for evaporation by the same factor (2) and reduces the droplet mass by a factor of eight - both these effects significantly increase the evaporation rate.

Optimum spray penetration and area coverage ensures uniform distribution of spraywater droplets in the steam flow. This is important for maximizing heat transfer from steam to the water droplets.

Spray Penetration

Spraywater penetration into the surrounding steam depends primarily on the size of the initial jet, momentum ratio between steam flow and injected spraywater and downstream distance and the distance from spraywater injection. Once the initial momentum of the injected spraywater is dissipated, the droplets mix with the surrounding steam and are carried further downstream suspended in the flow.

$$h = f\left\{\left(\frac{q_L}{q_G}\right), d_j, X\right\}$$

where,

h = spray penetration
q_L = momentum of spraywater jet
q_G = momentum of steam
d_j = jet diameter (or, spray sheet thickness)
X = distance from spraywater injection

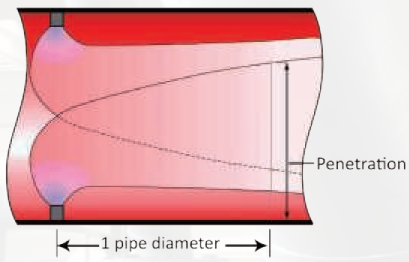


Fig. 3 Schematic of penetration of spray water in a cross flow of steam

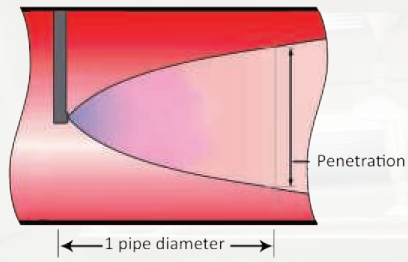


Fig. 4 Schematic of penetration of spray water in an inline flow of steam

Evaporation and Mixing

Evaporation of the suspended droplets progresses with heat transfer from the superheated steam. The time for complete evaporation of the injected spraywater depends on many factors; the most important among these factors are droplet size, the desired degree of superheat in the outlet steam, amount of spraywater (as % of steam) and local heat transfer coefficient. Uniform steam temperature downstream is achieved eventually, after all the spraywater is converted into steam and through turbulent mixing that occurs in the steam pipe.

The description above gives a simple overview of the physics. However, many design details need to be considered for each step to work correctly. Injection of correct amount of spraywater flow requires a reliable spraywater flow control across the entire operating range. Multi-stage pressure letdown design is required where the pressure drop across the flow control element is high. Spray nozzle selection, type and quantity, play a direct role in achieving fine atomization and correct spray penetration. Further, optimum division of the available pressure drop between the spraywater valve and the spray nozzles is an important part of the sizing process.

Desuperheater Selection and Sizing

The requirements for desuperheating applications range in severity from non-severe to very severe. It is the severe service applications that require most attention in selection and sizing. The severity of a desuperheating application depends on:

- Amount of cooling required (ΔTsteam)
- Amount of spraywater flow required (Wspray/Wsteam)
- Closeness of final steam temperature to saturation (Tsteam-final – Tsaturation)
- Range of steam flow rates (Wsteam-max : Wsteam-min)
- Range of spray water rates (Wsteam-max : Wsteam-min)
- Spray water ΔP available
- Installation related considerations

Some examples of applications where the desuperheating requirements are severe are turbine bypass, main steam and reheat steam attemperation, auxiliary steam system and process steam to export.

Calculations for atomization, spray penetration and evaporation require a realistic physical modeling of these processes. **KOSO** software used in the selection of optimum desuperheater design does all these. The detailed analysis permits accurate determination of the required distance to the first elbow and the downstream temperature feedback sensor.

The important rules based on physics and field experience which are followed in the sizing and selection of desuperheater technologies are:

- Droplet size should be less than 250 microns for all operating conditions
- Spray penetration should be between 15% - 85% of the pipe diameter to avoid impingement of cold water on hot metal boundaries (or parts)

Spraywater injection within a steam control valve body, sometimes known as "in-body desuperheating", should be avoided in severe service desuperheater applications; the risk of cold water hitting hot metal boundaries is too high, especially during transients.

Correct selection and sizing of desuperheaters is essential for high reliability of the plants which depend on them. It results in operation of processes which are stable and as per design intent for the related systems. Most of all, it is the key step to avoid catastrophic problems such as pipe or pressure boundary cracking, other damaging phenomenon like water hammer, and Unit trips because of poor control.

KOSO D-Series

KOSO D-Series family of desuperheaters covers the full range of applications that are typically required in steam plants. It includes all three spray nozzle technologies which are commonly used for water-injection: fixed-area (pressure-atomizing) type, variable-area type and steam-assist spray nozzles. The D-Series desuperheaters also include configurations that feature integrated spraywater flow control, which eliminates the need for a separate spraywater flow control valve.

D-Series		
Fixed area nozzle(s)	**DV1**	Venturi
	DVL	Venturi low-loss
	DVR	Venturi ring
	DPF	Probe
	DSR	Spray ring
Variable area nozzle(s)	**DPS**	Probe-type with spring-loaded nozzles
	DPW	Whirl-type nozzle
	DMR	Multinozzle ring with spring-loaded nozzles
Steam assist	**DAS**	Steam assist nozzle

The selection of desuperheater for a specific application depends very much on the process requirements in that service.

However, the fundamentals remain the same in all cases – small droplet sizes, avoiding impingement of spraywater on hot pressure boundary, correct control logic, good practices in piping layout etc. These designs can also be combined with control valves for steam-conditioning systems/ PRDS (Pressure-Reducing Desuperheating Systems).

Design details vary depending on application. Please refer to the data sheets for exact specifications. The Company's policy is one of continuous product improvement and reserves the right to modify the specifications contained herein without notice.

Fig. 5 Integral body flange type

Fig. 6 Butt weld type

Standard Features

Pressure boundary material	:	A182 F11/F22/F91
Steam pipe	:	2″ to 6″
Body Size	:	2″ to 6″ (standard)
Water pipe	:	1″
Connections	:	Steam : Flanged/BW Water : Flanged
Ratings	:	ASME 150 to 1500 - as standard ASME Sec. VIII Div I (Other ratings on request)
Spray water pressure	:	Minimum 5 bar (73 psi) above steam pressure*
Steam kinetic energy ($\frac{1}{2}$ ρV^2)	:	Minimum 200 Pa (0.03 psi) at the inlet
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	Up to 10:1 (depending on the system)
Achievable temperature	:	Up to 10°C of saturation for control with temperature feedback
Spray water control	:	Separate external control valve

*Excess pressure in the spraywater system is taken by the spraywater valve

DV1 Venturi

Description

- Simple construction
- Fixed-area spray nozzle
- For small line size with an upstream steam pressure-reducing valve (PRV)
- Relies on the energy of steam flow for atomization

Typical applications

- Process steam desuperheater downstream of existing steam PRV
- Small PRDS

DVL Low-Loss Venturi

Description

- Simple construction
- High spray water pressure is not required
- For small line size with or without an upstream steam PRV
- Relies on the energy of steam flow for atomization
- High rangeability

Typical applications

- Process steam desuperheating
- Small PRDS
- Ideal for applications where pressure drop in steam line has to be kept low

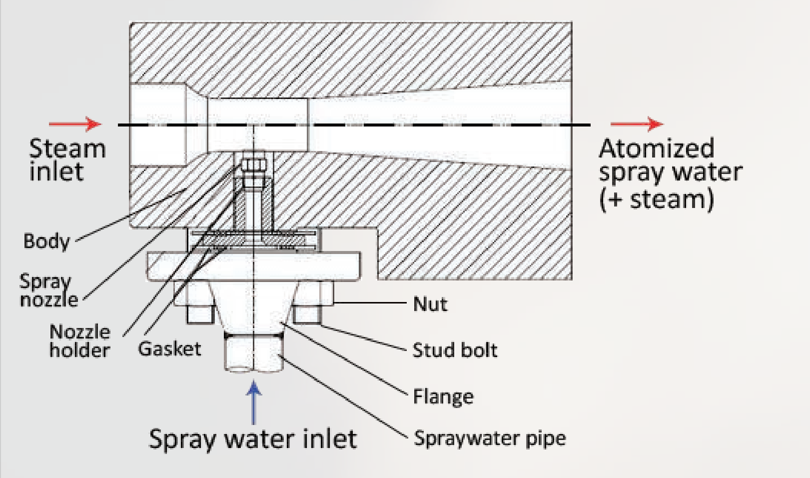


Fig. 7 Low pressure Loss Venturi desuperheater

Fig. 8
DVL desuperheater installed at the outlet of main steam valve in a steam PRDS

Standard Features		
Pressure boundary material	:	A182 F11/F22/F91
Steam pipe	:	2″ to 6″
Body Size	:	2″ to 6″ (standard)
Water pipe	:	1″
Connections	:	Steam : Flanged/BW Water : Flanged
Ratings	:	ASME 150 to 1500 standard ASME Sec. VIII Div I (Other ratings on request)
Spray water pressure	:	At least equal to steam pressure*
Steam kinetic energy (½ ρV²)	:	Minimum 200 Pa (0.03 psi) at the inlet
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	Up to 10:1 (depending on the system)
Achievable temperature	:	Up to 10°C of saturation for control with temperature feedback
Spray water control	:	Separate external control valve

*Particularly well-suited when the ΔP between water and steam is low; excess pressure in the spraywater system is taken by the spraywater valve

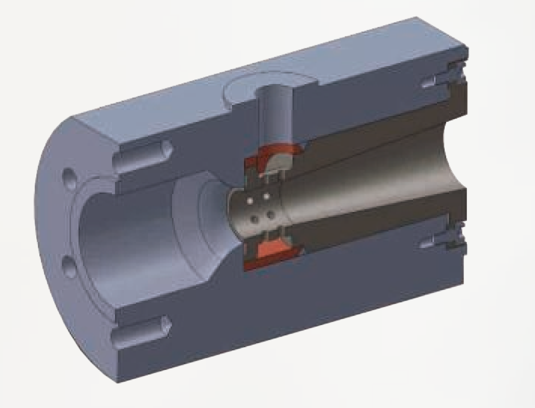


Fig. 9
Venturi ring with a low-loss pressure recovery zone at outlet

Fig. 10
Venturi ring DSH welded at the downstream of **KOSO** angle valve with a piston actuator

DVR Venturi Ring

Description

- Simple construction
- Fixed-area spray nozzles
- For small line size with an upstream steam pressure-reducing valve (PRV)
- Relies on the energy of steam flow for atomization

Typical applications

- Process steam desuperheating
- Small PRDS requiring large spraywater injection

Standard Features		
Pressure boundary material	:	A182 F11/F22/F91
Steam pipe	:	2″ to 6″
Body Size	:	2″ to 6″ (standard)
Water pipe	:	1″ to 2″
Connections	:	Steam : Flanged/BW Water : Flanged
Ratings	:	ASME 150 to 1500 standard ASME Sec. VIII Div. I & II (Other ratings on request)
Spray water pressure	:	Minimum 5 bar (73 psi) above steam pressure*
Steam kinetic energy ($\frac{1}{2}\rho V^2$)	:	Minimum 200 Pa (0.03 psi) at the inlet
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	Up to 10:1 (depending on the system)
Achievable temperature	:	Up to 10°C of saturation for control with temperature feedback
Spray water control	:	Separate external control valve

*Excess pressure in the spraywater system is taken by the spraywater valve

DPF Probe

Description

- Simple construction
- Fixed area spray injection
- Available with, or without, steam pipe

Typical applications

- Process steam desuperheater
- PRDS
- Non-severe process steam application

Fig. 11
Probe with fixed-area nozzle

Standard Features		
Pressure boundary material	:	A335 P11/A182 F11 A335 P22/A182 F22 A335 P91/A182 F91
Steam pipe	:	6" to 24"
Water pipe	:	1" to 3"
Connections	:	Steam stud : 3" to 5" Flanged Water : 2" to 3" Flanged
Ratings	:	ASME 150 to 1500 (Other ratings on request)
Spray water pressure	:	50 bar (750 psi) above steam pressure (recommended)*
Steam velocity	:	Minimum : 6 - 12 m/sec Maximum : 100 m/sec
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	4:1 typical
Achievable temperature	:	Up to 10°C of saturation
Spray water control	:	Separate external control valve

*Excess pressure in the spraywater system is taken by the spraywater valve

Fig. 12
Spray ring desuperheater with an outlet bell expander

Standard Features

Pressure boundary material	:	A335 P11/A182 F11 A335 P22/A182 F22 A335 P91/A182 F91
Steam pipe	:	6″ to 32″ (bell expander for connection to larger pipes downstream)
Water pipe	:	1″ to 6″
Connections	:	Steam pipe : Butt weld only Water pipe : BW/Flanged
Ratings	:	ASME B31.1 ASME VIII Div I, Job-rated (Other ratings on request)
Spray water pressure	:	Minimum 3.1 bar (45 psi) above steam pressure*
Steam kinetic energy ½ ρV^2)	:	Minimum 3 kPa (0.4 psi)
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	10:1 typical (for bypass to condenser)
Achievable temperature	:	Up to 10°C of saturation for control with temperature feedback (wet final steam condition requires feed- forward control)
Spray water control	:	Separate external control valve

*Excess pressure in the spraywater system is taken by the spraywater valve

DSR Spray Ring

Description

- Fixed area spray nozzles
- Relies on energy of steam flow for atomization
- Capable of injecting large amounts of spraywater

Typical applications

- HP turbine bypass to condenser
- HRH/LP bypass to condenser

DPS Probe

Description

- Spring-loaded variable area spray nozzle(s)
- Axial injection into the steam pipe
- Spray water throttling element is outside the steam pipe
- Available with, or without, steam pipe

Typical applications

- Main steam desuperheaters
- PRDS
- LP turbine bypass
- Process steam desuperheaters

Fig. 13
Stand-alone probe type with variable area Spring-loaded nozzle and flanged water inlet

Fig. 14
SL60 variable area spring-loaded nozzle

Standard Features		
Pressure boundary material	:	A335 P11/A182 F11 A335 P22/A182 F22 A335 P91/A182 F91
Steam pipe	:	6″ to 24″
Water pipe	:	1″ to 3″
Connections	:	Steam stud : 3″ to 5″ Flanged Water : 2″ to 3″ Flanged
Ratings	:	ASME 150 to 2500
Spray water pressure	:	Minimum 5 bar (73 psi) above steam pressure*
Steam velocity	:	Minimum : 6 - 12 m/sec Maximum : 100 m/sec
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	Water : 20:1 Steam : up to 15:1
Achievable temperature	:	Up to 10°C of saturation with temperature feedback system
Spray water control	:	Separate external control valve

*Excess pressure in the spraywater system is taken by the spraywater valve

Fig. 15
DPW Probe desuperheater mounted on the steam pipe

Standard Features

Pressure boundary material	:	A335 P11/A182 F11 A335 P22/A182 F22 A335 P91/A182 F91
Steam pipe	:	6″ to 32″
Water pipe	:	1″ to 3″
Connections	:	Steam stud : 3″ to 5″ Flanged Water : 2″ to 3″ Flanged
Ratings	:	ASME 150 to 2500
Spray water pressure	:	Model DPW - 4 : up to 40 bar Model DPW -10 : up to 100 bar
Steam velocity	:	Minimum : 6 - 12 m/sec Maximum : 125 m/sec
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	For water : up to 40 : 1
Achievable temperature	:	Up to 10°C of saturation for control with temperature feedback
Spray water control	:	Integrated within the desuperheater body
Shutoff	:	ANSI/FCI 70-2 Class 4
Actuator	:	G-series pneumatic diaphragm (Other types on request)

DPW Whirl Nozzle

Description

- Variable area spray swirl nozzle for fine atomization over a wide range integrated spraywater control valve
- Actuator type: Pneumatic Diaphragm as standard, other types on request
- Tight shut-off
- Simple installation-in vertical, horizontal or sloping pipe

Typical applications

- Process steam desuperheating
- Extraction steam desuperheating

DMR Multi-Nozzle Ring

Description

- Spring-loaded variable area spray nozzles
- Radial Injection into the steam pipe

Typical applications

- HP turbine bypass to cold reheat
- Turbine bypass to condenser
- PRDS
- Process steam desuperheating
- Auxiliary steam systems

Fig. 17 Multi-nozzle ring-type DSH

Fig. 16
DMR with dished end welded at the downstream of **KOSO** VectorA™ angle body valve with **KOSO** 6345LA double-acting piston actuator for HP turbine bypass

Standard Features		
Pressure boundary material	:	A335 P11/A182 F11 A335 P22/A182 F22 A335 P91/A182 F91
Steam pipe	:	6″ to 32″ (bell expander for connection to larger pipes downstream)
Water pipe	:	1″ to 6″
Connections	:	Steam pipe : Butt weld only Water pipe : BW/Flanged
Ratings	:	ASME B31.1 ASME VIII Div I, Job-rated
Spray water pressure	:	Minimum 5 bar (73 psi) above steam pressure*
Steam kinetic energy ($\frac{1}{2}\rho V^2$)	:	Minimum 3 kPa (0.4 psi)
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	Water : 20:1 typical Steam : 15:1
Achievable temperature	:	Up to 10°C of saturation for control with temperature feedback (wet final steam condition requires feed- forward control)
Spray water control	:	Separate external control valve

*Excess pressure in the spraywater system is taken by the spraywater valve

DAS Steam Assist Nozzle

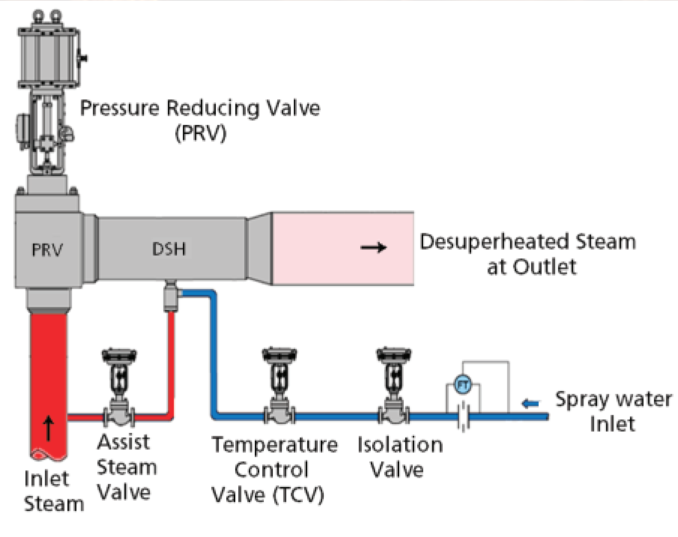


Fig. 18 DAS steam assist DSH system

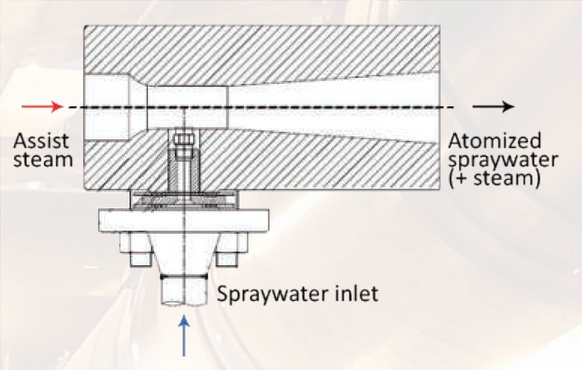


Fig. 19 Steam assist nozzle detail

Description

- Uses high – pressure steam to create very fine droplets
- Requires availability of high pressure steam for atomization
- Good mixing and evaporation at very low loads

Typical applications

- PRDS
- Severe process steam desuperheating

Standard Features		
Pressure boundary material	:	A335 P11/A182 F11 A335 P22/A182 F22 A335 P91/A182 F91
Steam pipe	:	6″ to 42″
Water pipe	:	1″ to 3″
Assist steam pipe	:	1″
Connections	:	Assist steam : Flanged Water pipe : Flanged/BW end
Ratings	:	ASME VIII Div. I job-rated
Spray water pressure	:	Minimum 10 bar (145 psi) above steam pressure* (recommended)
Steam kinetic energy (½ ρV^2)	:	Minimum 3 kPa (0.4 psi)
Assist steam pressure	:	Minimum 7 bar (100 psi) above the steam pressure
Steam velocity	:	Minimum 3 m/sec
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	40:1
Achievable temperature	:	Up to saturation with feed-forward control
Spray water control	:	Separate external control valve

*Excess pressure in the spraywater system is taken by the spraywater valve

T42 'Varitrol' Variable Area

KOSO continues to offer the classic T42 Desuperheater. This design has been widely used in the industry for over 30 years. It features variable-area spray and has an integrated spraywater flow control. Finely atomised spray coolant is injected into the steam through a series of propriety flat pattern spray jets, the opening of which is controlled at the point of injection.

Typical applications

- Process steam desuperheating
- PRDS (pressure-reducing-desuperheating-system)

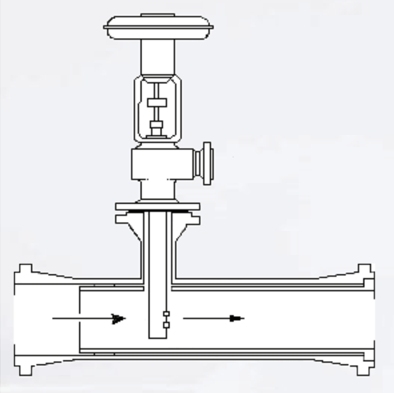


Fig 20
'Varitrol' Series 42 spray unit with pneumatic spring diaphragm actuator installed into steam pipe unit

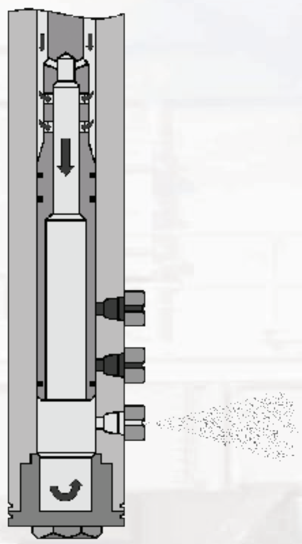


Fig 21
Varitrol spray unit showing multi - nozzles and push-to-close plug

Standard Features

Pressure boundary material	:	Chrome moly, carbon steel, stainless steel
Body size (water x steam)	:	1.5" x 3" or 2"x 4" based on capacity and rating
Connections	:	Steam Side : Flanged/ BW Water Side : Flanged only
Ratings	:	ASME 150 to 1500 - standard DIN PN20 to PN250 - optional (For other ratings, consult factory)
Spray water ΔP	:	Minimum : 2.1 bar (30 psi) Maximum : 50 bar (725 psi)
Steam velocity	:	Minimum : 6 - 10 m/sec Maximum : 100 m/sec
Water temperature	:	Minimum 50 °C (recommended)
Rangeability	:	(Consult Product Bulletin)
Achievable temperature	:	+8°C of saturation dependent on application
Spray water control	:	Integrated within the desuperheater body
Shutoff	:	ANSI/FCI 70-2 Class 4
Actuator	:	G-series pneumatic diaphragm (Other types on request)

*Excess pressure in the spraywater system is taken by the spraywater valve

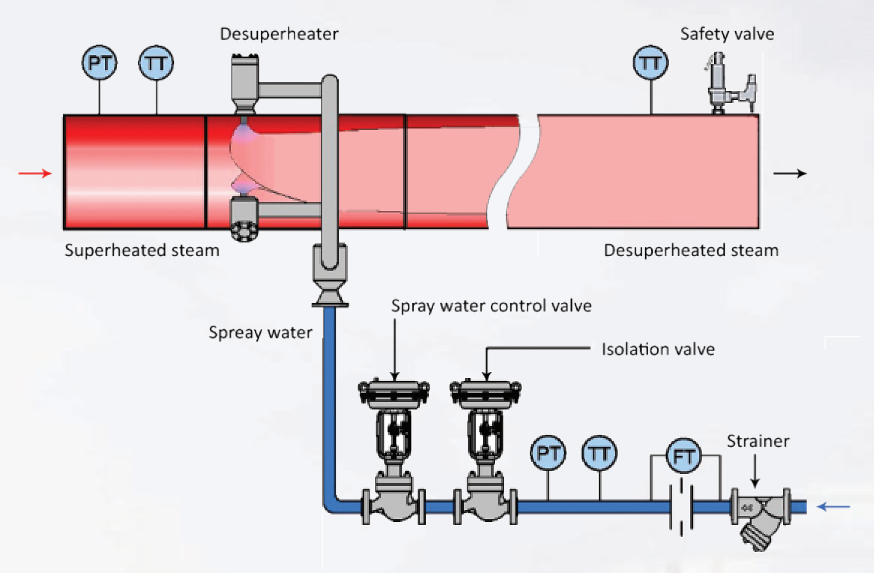


Fig. 22 An illustration of steam desuperheater installation

As with other types of instrument and equipment, proper installation is necessary for the correct operation of the desuperheater. The elements of installation that are important include:

- Piping layout, upstream and downstream
- Distance to the first elbow
- Distance to the temperature sensor
- Strainer, spraywater isolation valve
- Control logic, etc.

Desuperheater installation

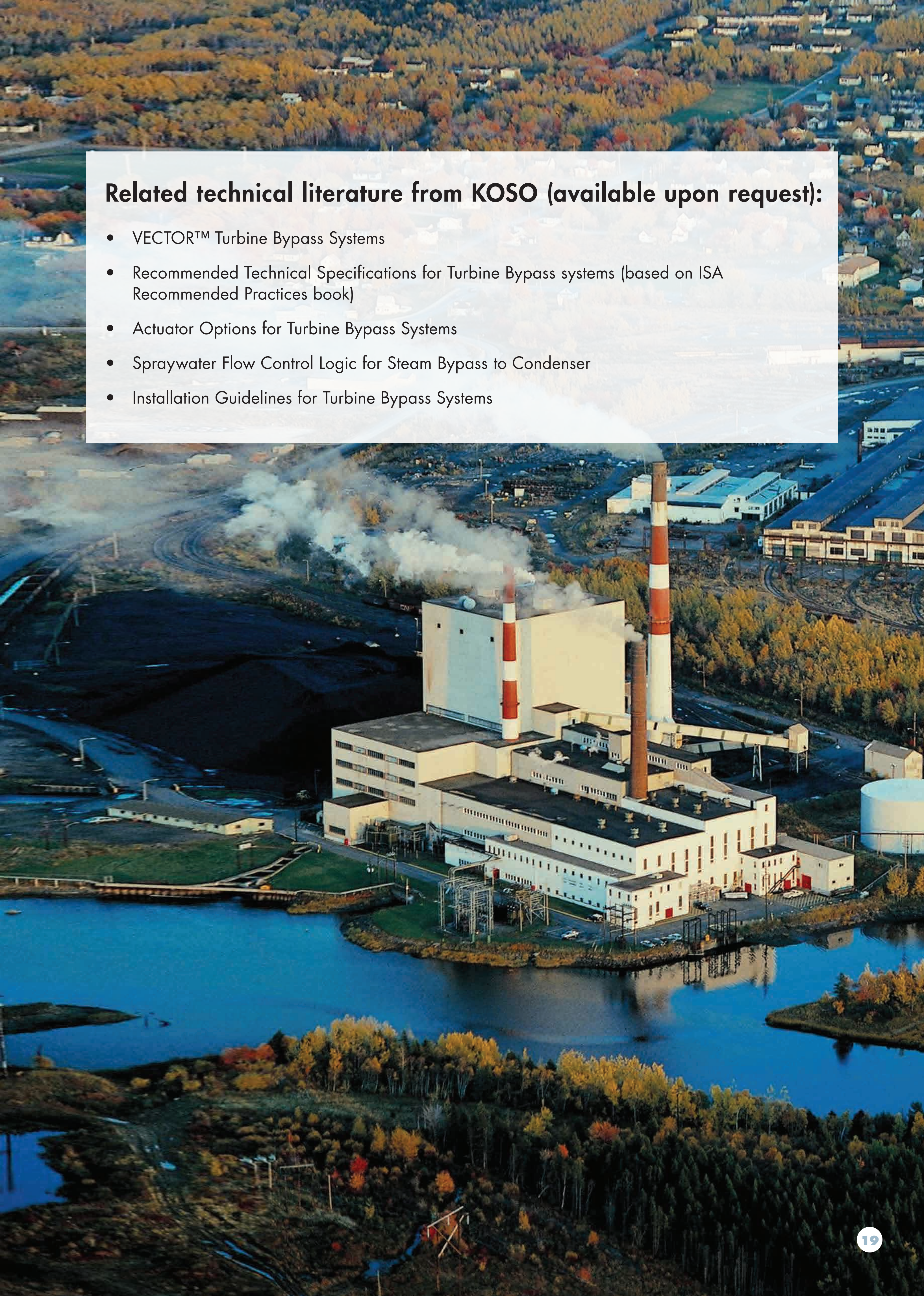
Some general guidelines are noted below:

- Spraywater piping in a desuperheating system should preferably be at an elevation below the injection point in the steam pipe.
- The minimum straight length required prior to water injection is ~ 5 pipe diameters.
- The minimum length of straight pipe required after water injection should provide at least 0.060 seconds residence time for water droplets; it should also be at least 6 pipe diameters long.
- Elevation of Steam pipework to fall in the direction of flow by a minimum 20 mm in 1000 mm.
- The residence time required for complete evaporation and mixing of the injected spraywater typically ranges from 100 milli-seconds to 500 milli-seconds. The minimum distance for temperature sensor from the spray injection is estimated on this basis. OEM recommendation shall be sought and followed.
- Temperature pockets should extend into the pipe 1/3 to 1/2 pipe diameter for steam pipes up to 300mm and 1/4 to 1/3 on steam pipe diameters above 300mm. Thermowells should be shielded from direct droplet impingement when the degree of final superheat is below 10°C.

KOSO recommends use of their technical experts in the design of new systems which require desuperheating or in solving problems with operating systems.

Some general guidelines (continued..):

- A flowmeter in the spraywater line is recommended for all desuperheating systems.
- Temperature feedback may be used for control of spraywater flow when the degree of final superheat is more than 10°C. Feed-forward control is required when the degree of final superheat is below 5°C.
- Spraywater isolation valve upstream of the spraywater control valve is recommended when the spray unit is required to shut off against a high differential pressure (above 35 bar-d). This is especially important for systems that require spraywater injection intermittently or infrequently.
- Efficient drainage of desuperheater pipework is essential. Large condensate traps for 10% maximum flow are recommended.
- Condensate supply must be free from debris and effectively filtered to 0.025 inches (0.66mm), which is approximately 30 U.S. mesh size strainer. Good practices in desuperheater system design require strainer upstream of the spraywater valve.
- A liner should be considered to protect against impingement of cold water on to hot steam pipe pressure boundary for applications with intermittent spraywater flow and when such possibility exists for expected transient conditions.
  NOTE - Correctly designed desuperheating systems for process steam applications with continuous flow generally do not require a liner.



Related technical literature from KOSO (available upon request):

- VECTOR™ Turbine Bypass Systems
- Recommended Technical Specifications for Turbine Bypass systems (based on ISA Recommended Practices book)
- Actuator Options for Turbine Bypass Systems
- Spraywater Flow Control Logic for Steam Bypass to Condenser
- Installation Guidelines for Turbine Bypass Systems

Visit us online for sales and service locations at: www.koso.co.jp

Headquarters
Nihon **KOSO** Co., LTD.
1-16-7, Nihombashi, Chuo-Ku
Tokyo, Japan, 103-0027
Tel: 81.3.5202.4100
Fax: 81.3.5202.1511
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