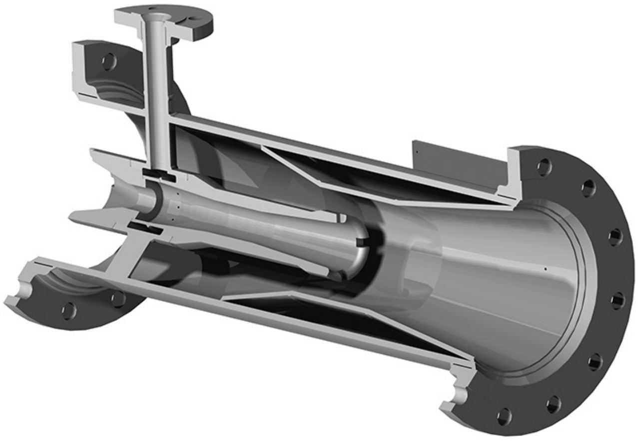
Desuperheater
Online Program Sizing Guidance

Desuperheater overview

In typical process plants, process steam is usually superheated, or heated to a temperature above saturation. The difference between the saturation temperature and the actual temperature of the steam is called 'superheat'.

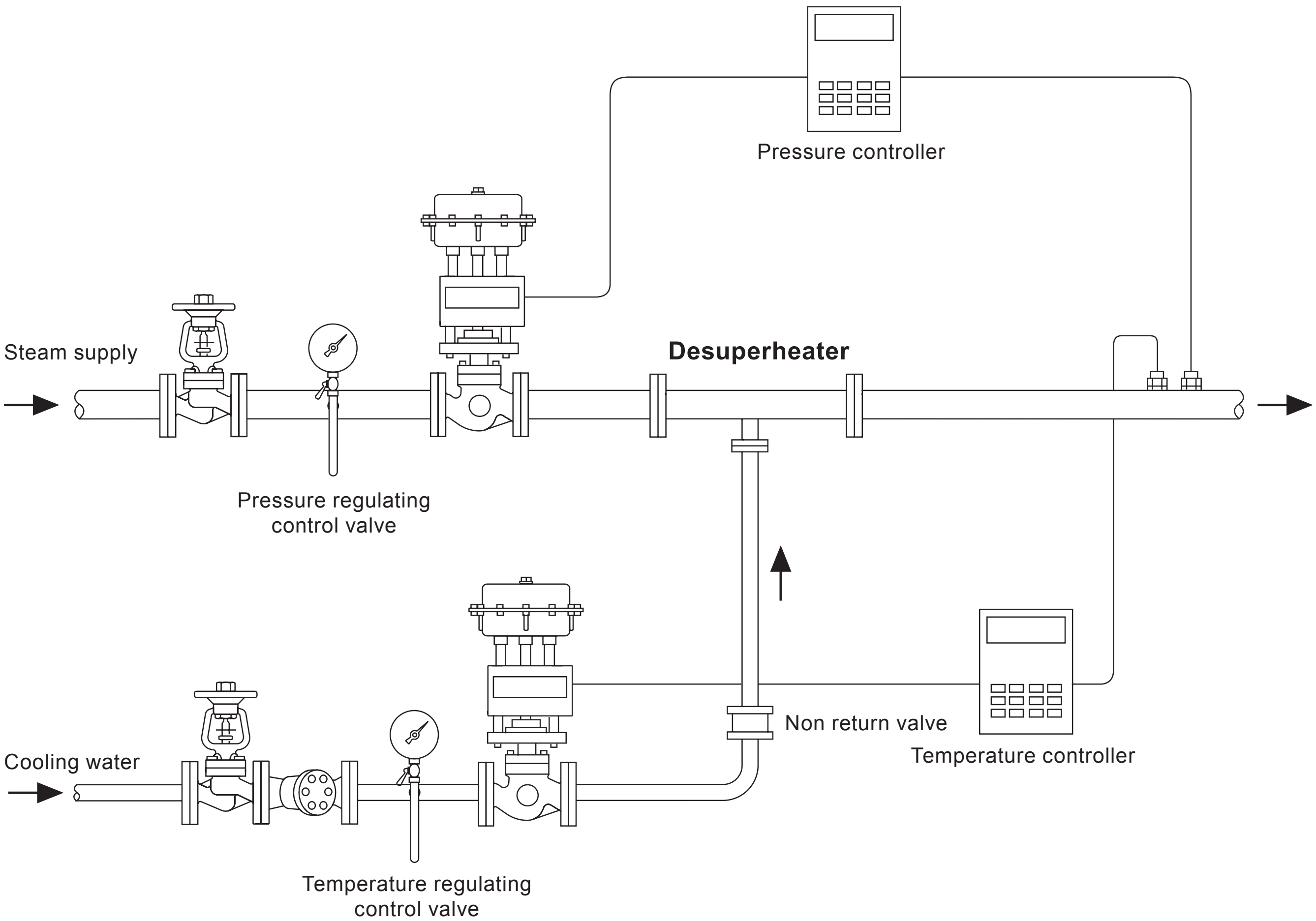
Desuperheated steam is more efficient in the transfer of thermal energy, consequently desuperheaters are used to bring the outlet degree of superheat closer to that of saturation.

Desuperheaters reduce the temperature of superheated process steam by introducing finely atomized cooling water droplets into the steam flow. As the droplets evaporate, sensible heat from the superheated steam is converted into latent heat of vaporization.



A typical desuperheater installation is shown below:

Combined pressure reducing / desuperheating station for venturi and spray type desuperheaters



Desuperheater selection

There are various types of desuperheater available so evaluation of the process duty is crucial to ensure selection of the right equipment. Turndown capability, pressure drop and outlet superheat play lead roles in desuperheater design and selection:

Turndown: (Maximum steam flowrate ÷ Minimum steam flowrate)

Turndown represents the variability of the steam flowrate. For many processes, turndown is very small or fixed. Generally, the higher the turndown, the more complicated the Desuperheater design.

Outlet superheat:

Although desuperheaters are capable of desuperheating to the saturation temperature of the steam, typically, desuperheaters are designed to produce steam temperatures at 3°C to 5°C above saturation. This is because it becomes increasingly difficult to control the process (and there is very little advantage) at lower temperatures.

Steam pressure drop (for venturi type desuperheaters):

For most pressure systems, a 0.4 to 0.7 bar g drop is considered reasonable. It should be noted that as the required turndown increases, so does the pressure drop. This is because there is a minimum acceptable pressure drop at the minimum flowrate case that ensures sufficient velocity to atomise the water droplets. Therefore, as the maximum steam flowrate increases, so does the velocity and hence the maximum pressure drop.

Water pressure drop (for spray type desuperheaters):

It should be noted that as the required turndown increases, the required cooling water pressure also increases.

General 'Rule-of-thumb':
Over-specifying the thermal load or process requirements is detrimental to efficient operation and will increase the cost of the desuperheater (and its controls). Under specifying the operating range can result in a unit that cannot handle all operating cases.

Each type of Spirax Sarco desuperheater, employs a different method to create water droplets. The process by which the water droplets are created is usually referred to as 'atomisation'.

It must be remembered that the evaporation of the water droplets (and hence cooling of the steam) is a time dependent process and does not occur instantaneously. Consequently, most of the desuperheating does not occur in the desuperheater itself, but in the pipework immediately downstream. Thus, the design of the downstream pipework is a crucial factor in a successful desuperheater installation.

It is important that the water droplets remain suspended in the downstream pipework for as long as possible. To ensure this, it is necessary to maintain sufficient turbulence in the downstream piping by keeping the velocity relatively high – higher than is usually encountered in steam distribution systems (up to 60 m/s). This is the reason why desuperheaters and their associated pipework are often (not always) smaller than the distribution system in which they are being installed.

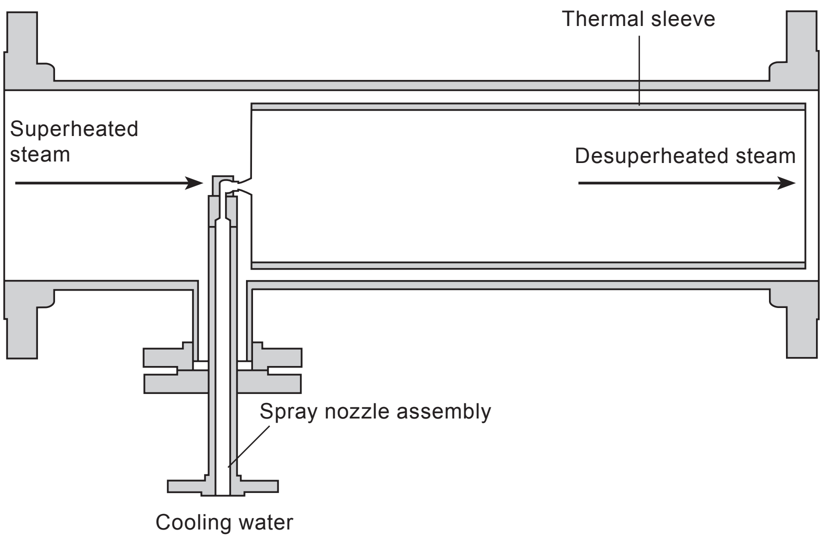
Types of desuperheater

From the foregoing paragraphs, it is easy to understand why there has to be a period of good contact between the droplets of cooling water the superheated steam. If good contact is lost, the water can no longer absorb heat effectively from the steam, evaporation stops and the desuperheating process comes to a halt.

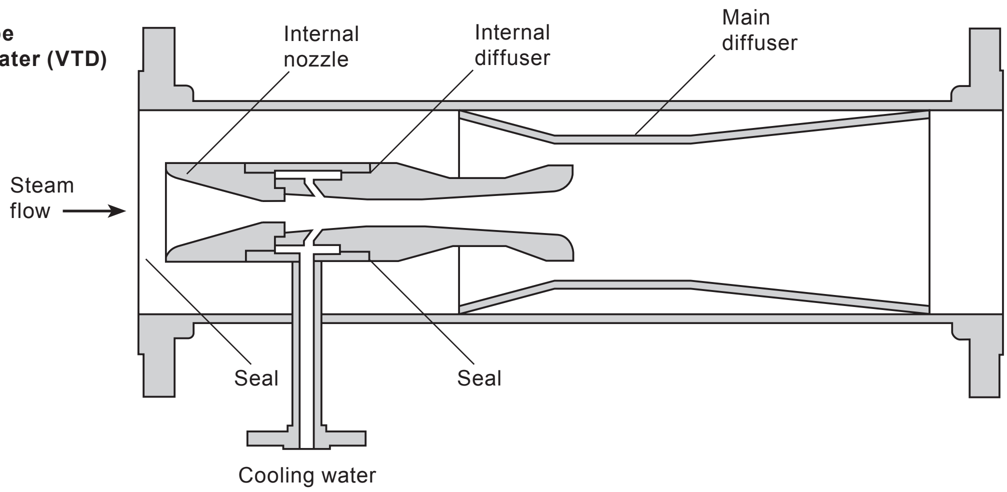
When the steam velocity is too low, 'water droplet fall-out' occurs and a pool of water is formed which runs along the bottom of pipe. At this point good contact between cooling water and the steam is lost and effective desuperheating will not occur. By following the guidelines presented in this document or using the Spirax Sarco online sizing software, problems due to droplet fall-out can be avoided.

There are three basic types of Spirax Sarco desuperheater (shown below) which all use a different method to atomise the cooling water droplets. Each one has its own merits and the desuperheater selection chart shown on the following page determines which type should be selected.

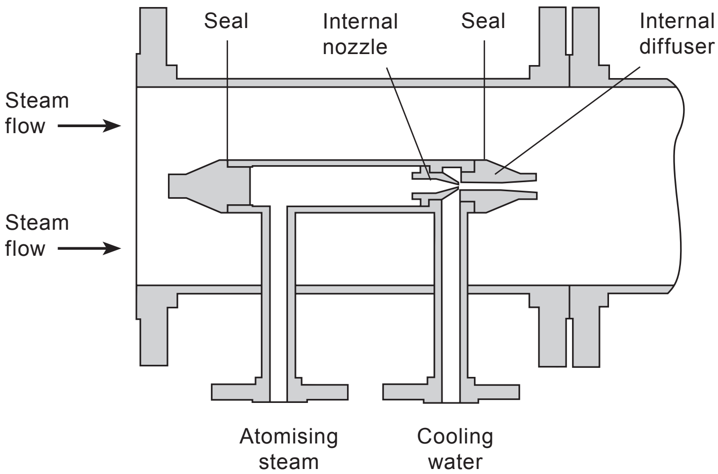
Complete spray type desuperheater (STD)

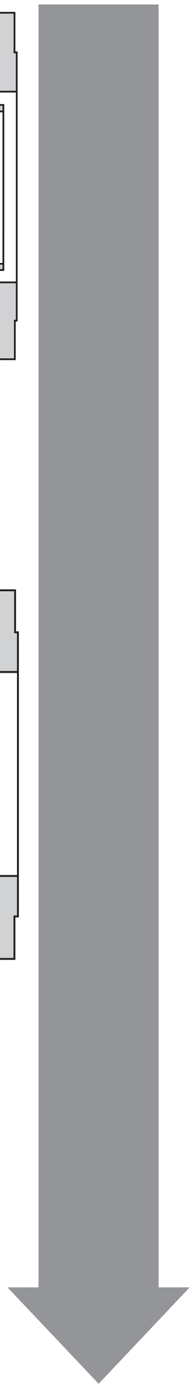


Venturi type desuperheater (VTD)



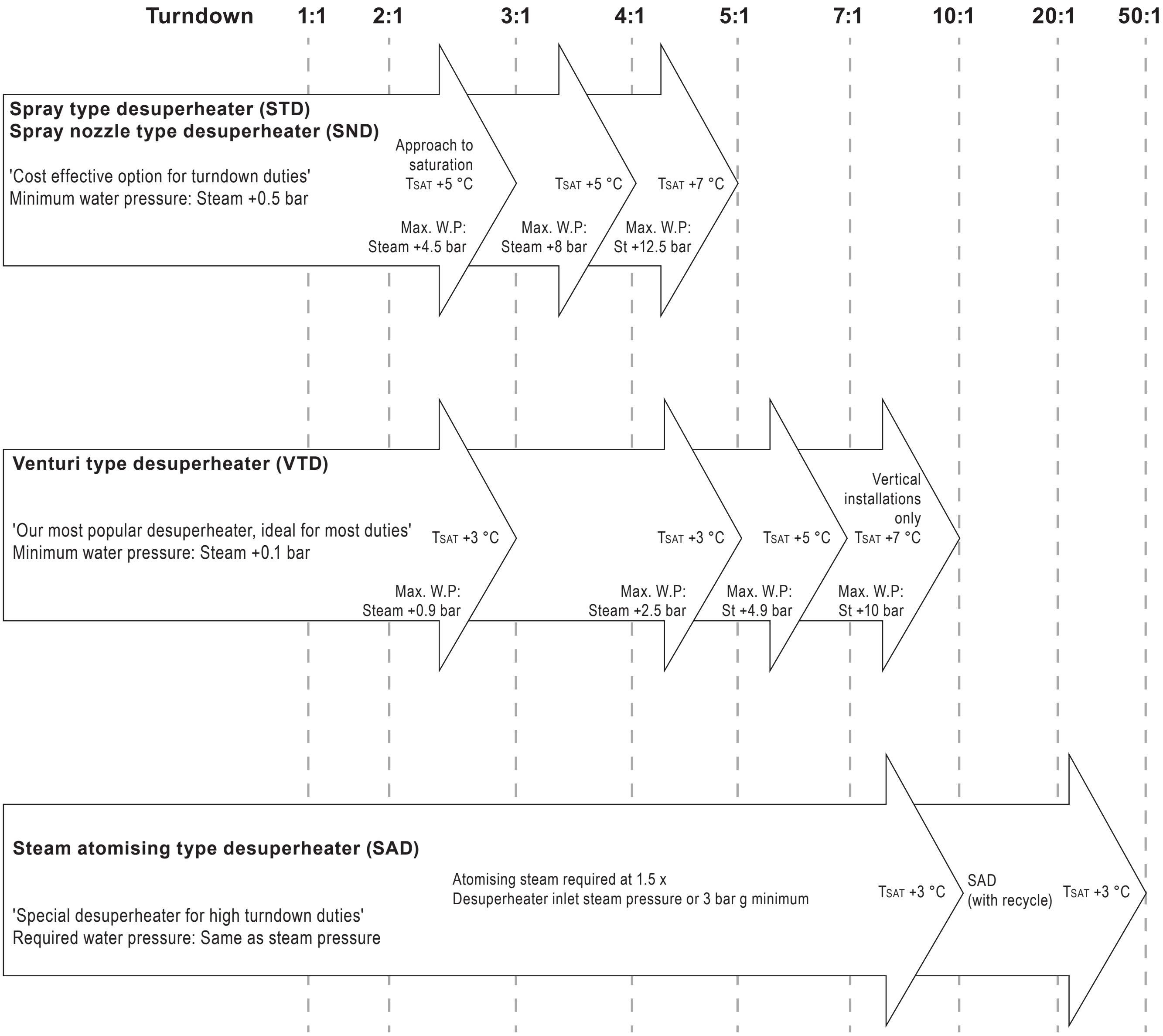
Steam atomising desuperheater (SAD)





Finer droplets, therefore smaller absorbtion length and / or better turndown and approach to saturation

Desuperheater selection chart



Other considerations

Desuperheater orientation

Desuperheaters may be installed either horizontally or vertically (with the steam flowing upwards). In a vertical installation, increased turndown can be achieved; as the steam and water are countered by gravity, the water is less likely to fall out of suspension. Spirax Sarco strongly advises against installations in which the steam flow is vertically downwards, as the opposite would occur.

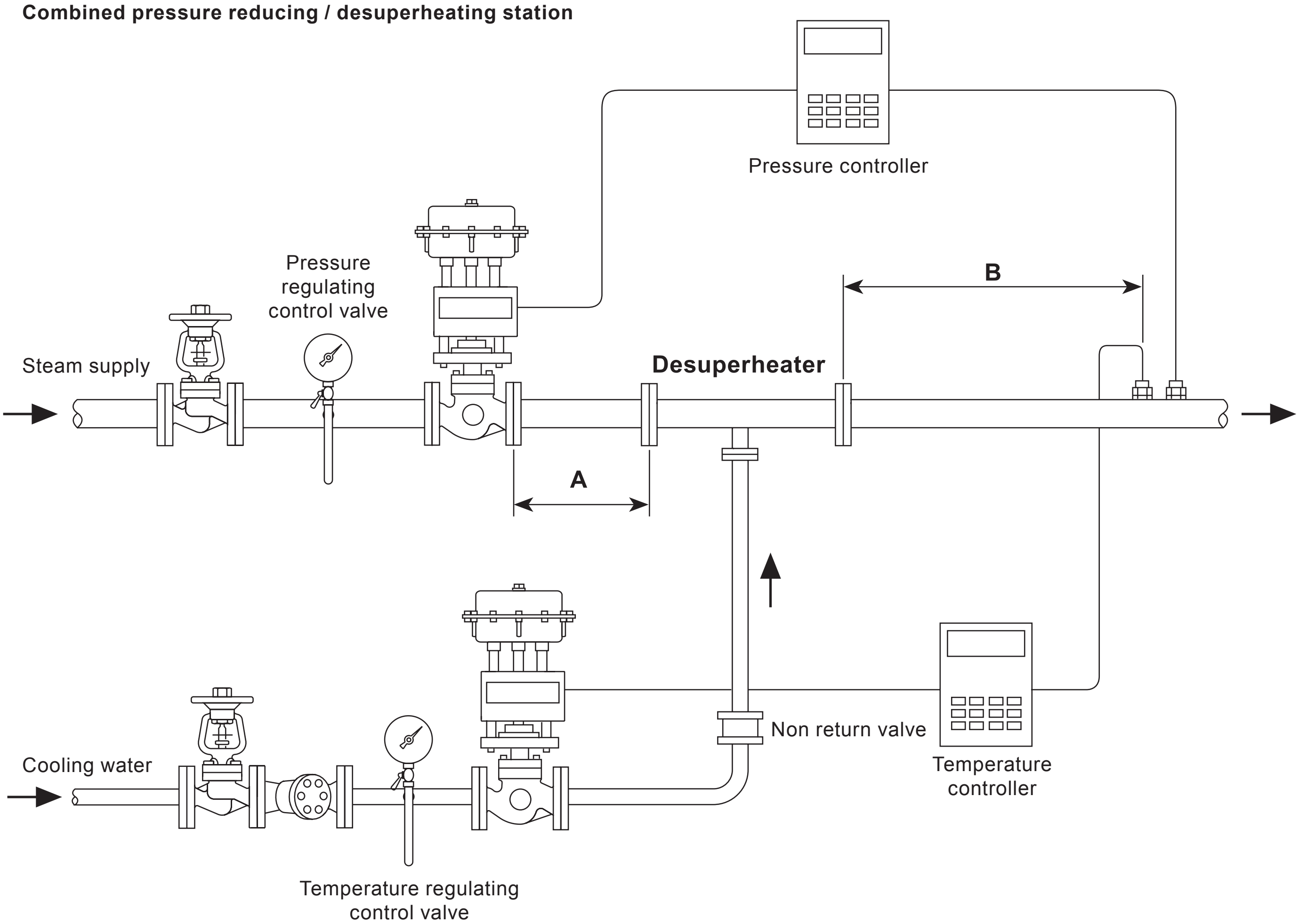
In the case of a horizontal installation the cooling water connection (and the atomising steam connection on a SAD (steam atomising desuperheater) should ideally point downwards, as this gives the best orientation for drainage of fluids in a shutdown situation. Other orientations are acceptable for satisfactory operation, but drainage is not as effective.

In a vertical installation we recommend that, the cooling water pipework (and atomising steam pipework, if applicable) should be brought to the desuperheater from below the corresponding connections on the desuperheater. This will provide the best layout for drainage of fluids on shutdown.

Distances

The diagram below indicates the recommended straight length distances between the desuperheater and upstream / downstream equipment. The distances are represented by length 'A' and 'B'.

Combined pressure reducing / desuperheating station



Recommended distances for location of pressure and temperature sensors and equipment:

	Residual superheat	100 °C	50 °C	30 °C	15 °C	10 °C	5 °C
B	**Downstream distance required (straight)**	2.5 m	3.7 m	5.0 m	6.25 m	6.8 m	7.5 m
A	**Upstream distance required (straight)**	The greater of 5 pipe diameters or 1.5 m					

'The greater the residual superheat, the faster the water droplets are absorbed'

Other considerations (continued)

Cooling water supply

Typical cooling water supply options are as follows:

- Boiler feedwater (BFW) (taken from the pressure side of the boiler feedpump).
- Demineralised water.
- De-ionised water.
- Condensate.

Town's water or process water may also be used, but depending on hardness, salts may be deposited on the inside of downstream pipework and the face of valve seats and plugs.

Cooling water quality

The quality of the injected water is important. The TDS (Total Dissolved Solids) of the injection water should be as low as possible since all these solids will come out of solution and be deposited on the faces of valves and could block up the small orifices in the desuperheater nozzles.

Cooling water temperature

Generally, the hotter the better. This is because hot droplets need to absorb less heat to reach their flash temperature than cold ones. Hence, hot droplets will evaporate more quickly, producing a more efficient desuperheating process. Using hot water also has the additional advantage that smaller amounts of water will fall onto the inside walls of the pipework.

Because of the benefits of using hot water, it is logical to insulate the water supply pipes to minimise heat loss.

Cooling water pressure and flowrate

In order to inject the cooling water, its pressure at the desuperheater nozzle must be equal to or greater than the operating steam pressure in the pipe. The requirement varies from one type of desuperheater to another, but typical minimum values are:

- Spray type desuperheater	steam pressure + 0.5 bar
- Venturi type desuperheater	steam pressure + 0.1 bar
- Steam atomising type desuperheater	equal to steam pressure

For the spray and Venturi type desuperheaters, the highest water inlet pressure required will be at the highest cooling water flowrate.

It should be noted that the water flowrate is a function of the square of the pressure difference between cooling water and the steam. So if the water flowrate is to be increased by a factor of 4 for example, then the pressure difference must increase by a factor of 4^2 = 16. This is the reason why it is important not to over-specify the turndown as high cooling water pressures are quickly reached (especially with spray type desuperheaters).

If an independent or booster pump is used, a spill-back will be required to ensure that there is always flow through the pump.

Cooling water control valve

A pressure drop will be required over the water control valve. We have already said that ideally the water should be as hot as possible so care is needed to ensure that flashing conditions do not exist across the control valve.

Superheated steam pressure control

It is desirable that a constant steam supply pressure be maintained.

The temperature of the steam after the desuperheater controls the amount of water added. The higher the temperature, the more the control valve will open and the greater the amount of water that is added. Usually the target is to reduce the steam temperature to within a small margin of saturation temperature. In virtually all applications the upstream pressure will be controlled and constant, however, if the superheated steam supply pressure is increased, the saturation temperature will also increase. The set value on the Controller will not change, and an excessive amount of water will be added as the control system tries to achieve the set temperature. This would result in very wet saturated steam with its attendant problems.

Control

In this document we have frequently used the term 'turndown' to describe the performance of the different types of desuperheater. However, as far as an installation is concerned, it should remembered that the desuperheater is only one element of a desuperheating station. Obviously, if the controls that are fitted have lower turndown than the desuperheater, then the turndown of the desuperheater station will be reduced.

For example, in a particular pressure reducing / desuperheating station, the rangability of the cooling water valve may not be as high as the desuperheater. In this case it will be the rangability of the water control valve that limits the turndown of the desuperheating station.

Separator station

In applications where there must be no moisture present in the resulting steam (such as prior to a turbine for example) it is recommended that a separator is installed downstream of the desuperheater. This will protect downstream pipework and equipment from the effects of moisture in the event of a control system failure or abnormal operating conditions, for example at start-up.

The separator must be located after the temperature sensor thereby giving the water droplets as much time as possible to evaporate.

Strainer

Spirax Sarco recommend that a strainer is incorporated in the cooling water supply line to protect both the cooling water control valve and the small bores within the desuperheater from becoming blocked.

Isolation valves

To allow maintenance to be safely carried out, isolation valves are recommended upstream of:

- The superheated steam pressure control valve.
- The cooling water control valve.

Safety valve

In applications involving simultaneous pressure reduction, a safety relief valve may be needed to protect both the desuperheater and downstream equipment from the effects of:

- Excess pressure in the event of pressure control system failure.
- Excess temperature in the event of temperature control system failure.

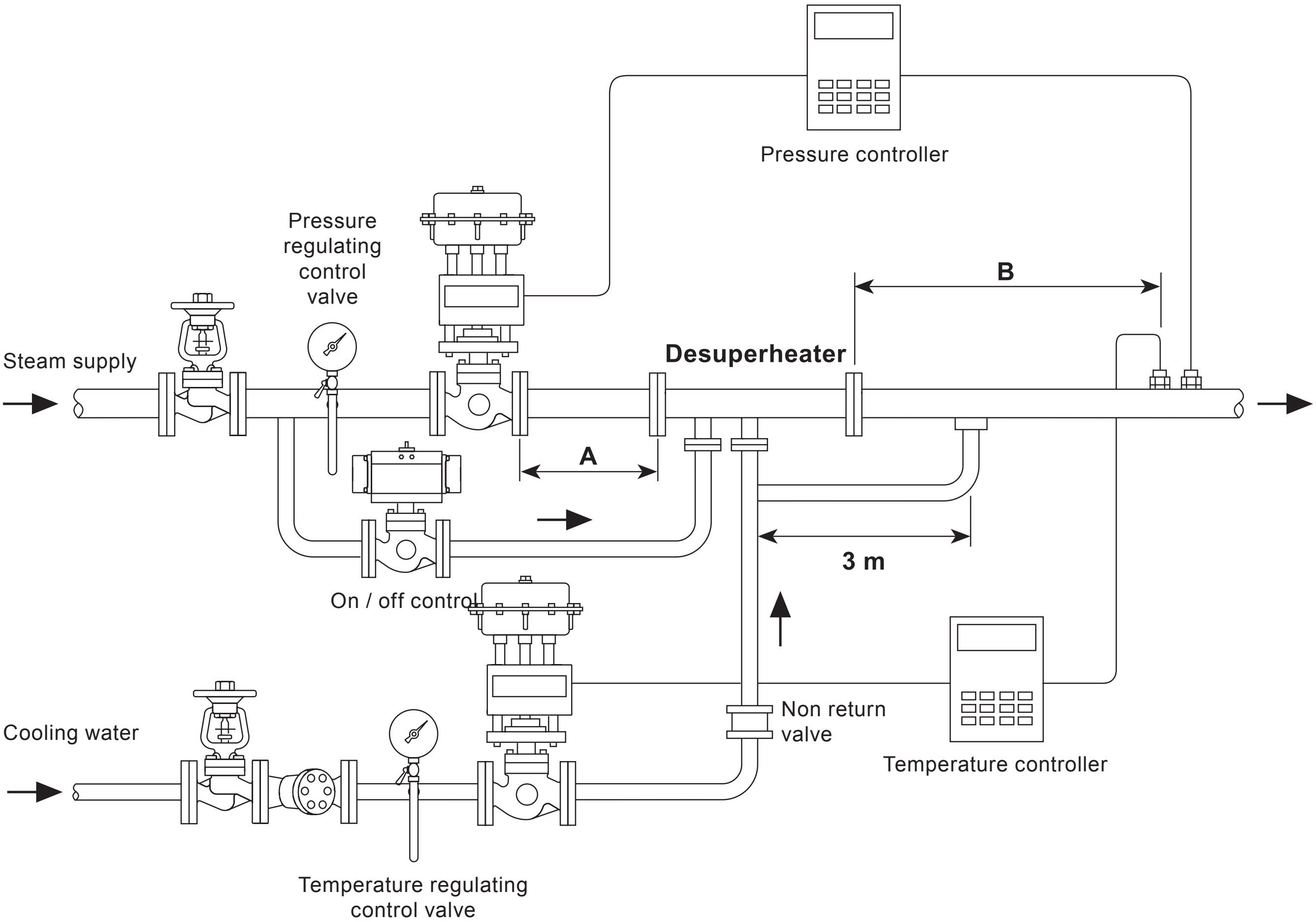
It is essential that the desuperheater and downstream equipment are suitable for the maximum temperature of the superheated steam. This is to protect these items in the event of a failure of both the pressure and temperature control systems.

Recycle loop

For SAD steam atomising desuperheaters with a very high turndown a 'catchpot and recycle loop' are often installed as shown on the diagram below. The recycled condensate is hot which leads to faster absorption.

The desuperheater generates a small suction effect to draw the recycle water back to the desuperheater ensuring that the water doesn't 'by-pass' the desuperheater.

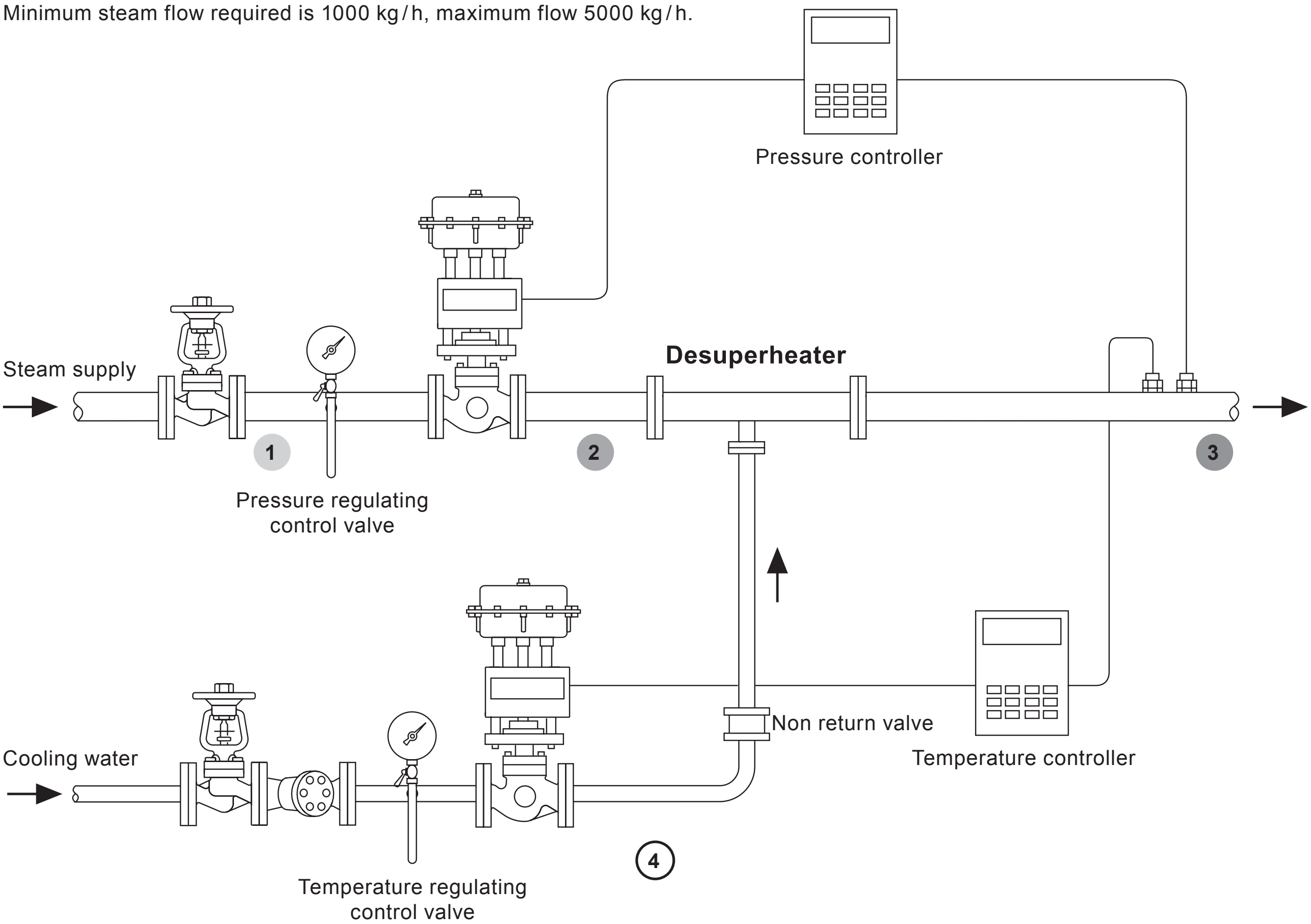
Combined pressure reducing / desuperheating station for steam atomising type desuperheaters



Detailed example

Steam is required to heat a vessel jacket at 2 bar g and 133.7ºC. A low pressure steam supply is available at 10 bar g and 200 °C for this purpose.

Condensate at 95 °C and 5 bar g is available as the cooling medium.
Minimum steam flow required is 1000 kg/h, maximum flow 5000 kg/h.



Method

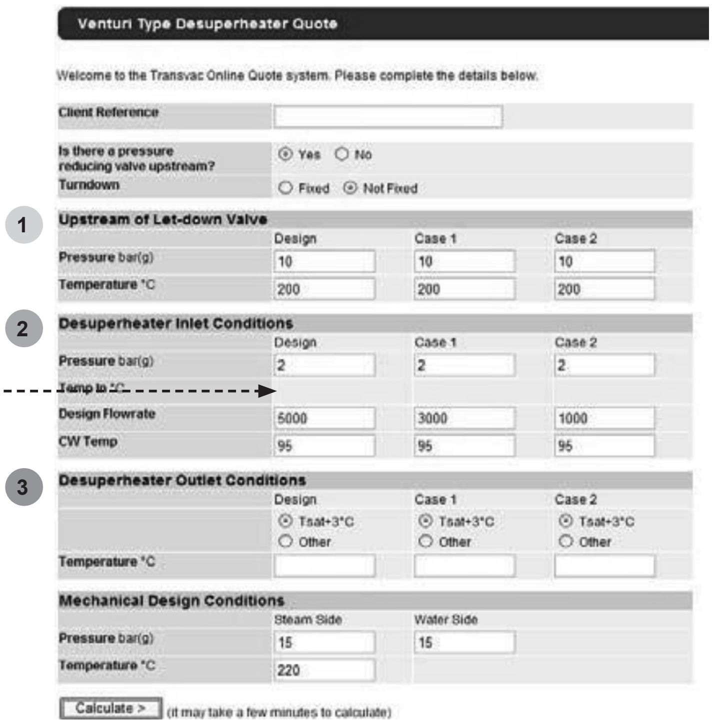
As the turndown required equals 5:1 and the application involves simultaneous pressure reduction, this would seem to be a good application for a venturi type desuperheater (VTD). Please note that a steam atomising desuperheater (SAD) could also be used for this duty, but the overall installation cost would be higher due to the greater complexity of the installation.

As already stated, it is not possible to control at the saturated temperature of the steam so any associated temperature controller should have a set point of 3 °C above the saturation temperature (which is 136.7ºC in this example).

We can use the Spirax Sarco Online Sizing Program to calculate the unit size (available at www.spiraxsarco.com/uk with password). The form would be completed as follows:

The steam temperature at the inlet to the desuperheater is calculated by the program automatically and is shown on the datasheet.

Once the calculation button is pressed the software will calculate the required cooling water pressure and flowrate. It will also calculate the pressure drop across the unit. The user will see a summary screen, at which point the desired flange rating can be selected and then the 'Save & Email' button can be pressed. You will then receive an e-mail with a drawing and datasheet to your chosen e-mail address.



Venturi Type Desuperheater Quote

Welcome to the Transvac Online Quote system. Please complete the details below.

Client Reference

Is there a pressure reducing valve upstream? ⦿ Yes ○ No
Turndown ○ Fixed ⦿ Not Fixed

1 Upstream of Let-down Valve	Design	Case 1	Case 2
Pressure bar(g)	10	10	10
Temperature °C	200	200	200

2 Desuperheater Inlet Conditions	Design	Case 1	Case 2
Pressure bar(g)	2	2	2
Temp to °C			
Design Flowrate	5000	3000	1000
CW Temp	95	95	95

3 Desuperheater Outlet Conditions	Design	Case 1	Case 2
	⦿ Tsat+3°C ○ Other	⦿ Tsat+3°C ○ Other	⦿ Tsat+3°C ○ Other
Temperature °C			

Mechanical Design Conditions	Steam Side	Water Side
Pressure bar(g)	15	15
Temperature °C	220	

Calculate > (it may take a few minutes to calculate)

Detailed example (continued)

The datasheet generated by the program for this example is as follows:

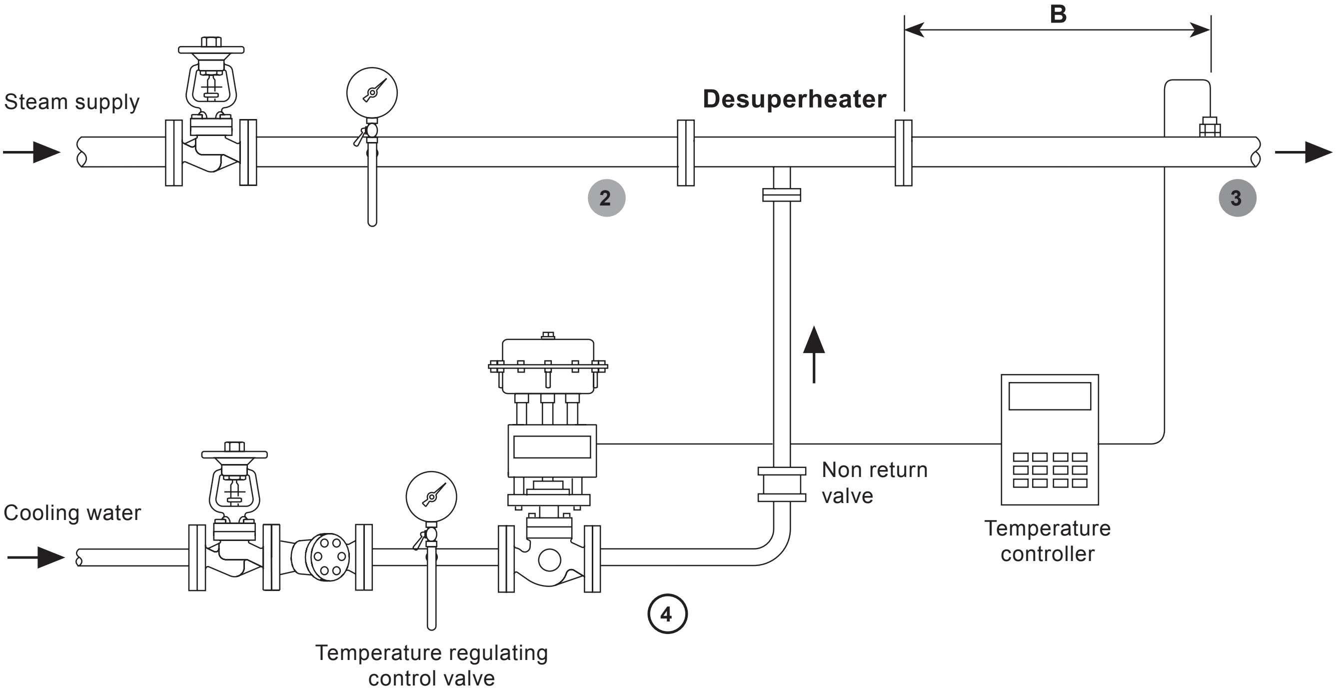
		Spirax Sarco Venturi Type Desuperheater Data Sheet						v 1.4	
	1	Client :	Spirax-Sarco Limited			Client Project Ref :			
	2	Client's Ref :	EXAMPLE CALCULATION			Plant Location :			
	3	Spirax Sarco Ref :	VTD01582			Equip. Item No. :			
	4	Description :	Size 6 Venturi Type Desuperheater			No. OFF :	1		
	5	Unit Ref :	VTD150 °CS6F0			Operation :			
	6	Drawing No. :	DE-VTDSDSO			Serial No. :			
	7	Unit Size :	6						
	8	**INLET CONDITIONS**	Case 1	Case 2	Case 3	**CONDITIONS UPSTREAM OF LET-DOWN VALVE**			
2	9	Flowrate (kg/hr)	5000	3000	1000	Case 1	Case 2	Case 3	1
	10	Pressure (bar g)	2.302	2.108	2.012	10	10	10	
	11	Temperature (°C)	179.7	179.2	178.9	200	200	200	
	12								
	13	**COOLING MEDIUM**	Case 1	Case 2	Case 3				
	14	Flowrate (kg/hr)	193.5	116.1	38.7				
4	15	Pressure (bar g)	5.34	3.2	2.13				
	16	Temperature (°C)	95	95	95				
	17	Medium -		Water					
	18								
	19	**DISCHARGE CONDITIONS**	Case 1	Case 2	Case 3				
3	20	Pressure (bar g)	2	2	2				
	21	Temperature (°C)	136.7	136.7	136.7				
	22	Flowrate (kg/hr)	5193.5	3116.1	1038.7				
	23								
	24	**MATERIALS OF CONSTRUCTION**				Flanges	Carbon Steel ASTM A 105		
	25	Main Body	Carbon Steel ASTM A 106 Grade B			Gaskets	Soft Copper		
	26	Inner Nozzle	Stainless Steel BS 970 S11/13			Inner Body	Carbon Steel ASTM A350 LF2		
	27	Inner Venturi	Stainless Steel BS 970 S11/13			Main Venturi	C.Steel BS 1501-151/161-430A/B		
	28								
	29	**MECHANICAL DESIGN**	Steam	Water		CONNECTION DETAILS			
	30		Side	Side			Size	Rating	
	31	Max.Design Pressure (bar g)	15	15		Inlet Steam	6	300 LB	
	32	Max. Design Temperature (°C)	220	220		Discharge Steam	6	300 LB	
	33	Internal Corrosion Allowance (mm)	1.5	1.5		Cooling Medium	1	300 LB	
	34	Mechanical Design Code	ASME B31.3			Flange Type	ASME B16.5 Slip-On		
	35	Welding Standard	To Code						
	36	External Surface Finish	High Temp. Silicone Aluminium						
	37	Weight (kg)	68						
	38								
	39	**DIMENSIONS**							
	40	A (" NB) 6							
	41	B (mm) 178							
	42	C (mm) 127							
	43	D (mm) 533							
	44	E (mm) 660	Note: Letters refer to Drawing						
	0	Issued for sizing only			PDA	08/01/2010			
	Rev	Description			By	Date	Checked	Date	

A Spirax Sarco Size 6 venturi type desuperheater has been selected. It can be seen from the 'Cooling Medium' section that the maximum cooling water pressure required is 5.34 bar g consequently a water booster pump should also be installed (as the cooling water is only available at 5 bar g.

The program has calculated a steam pressure drop across the desuperheater of 0.302 bar g (maximum). As there is a pressure reducing valve installed, the program has automatically added this pressure drop to the desuperheater inlet pressure to 'compensate' for the pressure drop. This will ensure that the outlet pressure from the desuperheater is 2 bar g. The datasheet therefore shows the correct pressures and flowrates for sizing both the pressure reducing valve and the water control valve.

Detailed example 2

Steam is required at 5 bar g (saturated) for use in a Shell & Tube Heat Exchanger. The Client has steam available at 5 bar g, 350 °C. Minimum steam flow is 8 500 kg / h, maximum is 25 000 kg / h. Boiler feedwater at 20 °C is available as the cooling medium.



Method

As the turndown is approximately 3:1 we can select any type of Desuperheater. There are 3 options:

SAD - Steam atomising desuperheater
This would require atomising steam at 7.5 bar g (min).

VTD - Venturi type desuperheater
This could be selected, however, this desuperheater is not part of a pressure reducing station, consequently if we select a VTD venturi type desuperheater, the discharge steam pressure will be reduced by the pressure drop across the unit. The steam could be desuperheated to Tsat+3 °C.

STD - Spray type desuperheater
The unit is capable of handling the turndown with no steam-side pressure drop and can desuperheat to Tsat+5 °C.

In this case the client states that Tsat+5 °C is acceptable so we will select an STD.

The Spirax Sarco Online Spray Type Desuperheater Sizing Program would be completed as shown opposite:

Spray Type Desuperheater Quote

Welcome to the Transvac Online Quote system. Please complete the details below.

Client Reference	DETAILED EXAMPLE 2		
Is there a pressure reducing valve upstream?	○ Yes ⊙ No		
Turndown	○ Fixed ⊙ Not Fixed		
Upstream of Let-down Valve			
	Design	Case 1	Case 2
Pressure bar(g)			
Temperature °C			
Desuperheater Inlet Conditions			
	Design	Case 1	Case 2
Pressure bar(g)	5	5	5
Temp In °C	350	350	350
Flowrate kg/h	25000	18000	8500
CW Temp °C	25	25	25
Desuperheater Outlet Conditions			
	Design	Case 1	Case 2
	⊙ Tsat+5°C ○ Other	⊙ Tsat+5°C ○ Other	⊙ Tsat+5°C ○ Other
Temperature °C			
Mechanical Design Conditions			
	Steam Side	Water Side	
Pressure bar(g)	10	30	
Temperature °C	374		

Calculate > (it may take a few minutes to calculate)

This section does not need to be completed

Detailed example 2 (continued)

A Spirax Sarco Size 10 spray type desuperheater has been selected. The maximum cooling water pressure required is 9.79 bar g and there is a negligible steam-side pressure drop.

Spirax Sarco Spray Type Desuperheater Data Sheet

v2.0

	1	Client :	Spirax-Sarco Limited			Client Project Ref :		
	2	Client's Ref :	DETAILED EXAMPLE 2			Plant Location :		
	3	Spirax Sarco Ref :	STD00519			Equip. Item No. :		
	4	Description :	Size 10 Spray Type Desuperheater			No. OFF :	1	
	5	Unit Ref :	Size STD250CS6F0			Operation :		
	6	Drawing No. :	DESTD00519-1			Serial No. :		
	7	Unit Size :	10					
2	8	**INLET CONDITIONS**	Case 1	Case 2	Case 3	**CONDITIONS UPSTREAM OF LET-DOWN VALVE**		
	9	Flowrate (kg/hr)	25000	18000	8500	Case 1	Case 2	Case 3
	10	Pressure (bar g)	5	5	5			
	11	Temperature (°C)	350	350	350			
	12							
4	13	**COOLING MEDIUM**	Case 1	Case 2	Case 3			
	14	Flowrate (kg/hr)	3733	2678.8	1269.2			
	15	Pressure (bar g)	9.79	7.48	5.55			
	16	Temperature (°C)	25	25	25			
	17	Medium -	Water					
	18							
3	19	**DISCHARGE CONDITIONS**	Case 1	Case 2	Case 3			
	20	Pressure (bar g)	5	5	5			
	21	Temperature (°C)	163.9	163.9	163.9			
	22	Flowrate (kg/hr)	28733	20687.8	9769.2			
	23							
	24	**MATERIALS OF CONSTRUCTION**				Nozzle Housing	Carbon Steel ASTM A 350 LF2	
	25	Main Body	Carbon Steel ASTM A 106 Grade B			Flanges	Carbon Steel ASTM A 105	
	26	Water Branch	Carbon Steel ASTM A 106 Grade B			Gaskets	Soft Copper	
	27	Thermal Sleeve	Stainless Steel ASTM A312 TP316L			Spray Nozzle	Stainless Steel	
	28							
	29	**MECHANICAL DESIGN**	Steam	Water		**CONNECTION DETAILS**		
	30		Side	Side			Size	Rating
	31	Max.Design Pressure (bar g)	10	30		Inlet Steam	10	300 LB
	32	Max. Design Temperature (°C)	374	374		Discharge Steam	10	300 LB
	33	Internal Corrosion Allowance (mm)	1.5	1.5		Cooling Medium	2	300 LB
	34	Mechanical Design Code -	ASME B31.3			Flange Type	ASME B16.5 Slip-On	
	35	Welding Standard -	To Code					
	36	External Surface Finish -	High Temp. Silicone Aluminium					
	37	Weight (kg)	180					
	38							
	39	**DIMENSIONS**						
	40	A (" NB)	10					
	41	B (mm)	430					
	42	C (mm)	250					
	43	D (mm)	800					
	44	E (mm)	1050	Note: Letters refer to Drawing				
	0	Issued for sizing only			PDA	22/01/2010		
	Rev	Description			By	Date	Checked	Date

Typical applications

The following is a list of applications where desuperheaters have been supplied:

Power generation

To reduce the temperature of steam discharged from turbine bypass systems to that required for other parts of the plant.

- Turbine washing

Process industries

In process industries, desuperheaters are used as part of a system for reducing the temperature and pressure of steam from boilers to economic levels of operation.

Paper and board industry

- Paper drying machines

Food industry

- Steam cooking kettles
- Evaporator heat exchanger
- Product conditioning

Textile industry

- Fabric finishing autoclaves

Tobacco industry

- Tobacco leaf drying plants

Chemical and pharmaceutical industry

- Reactor heater jackets and coils
- Steam supply to process heaters

Oil and petrochemical industry

- Vacuum distillation start-up heaters
- Steam supply to process heaters
- Let-down station and turbine bypass
- Thermocompressor discharge
- Mechanical vapour re-compression

Brewing and distilling industry

- Steam heating system

Boiler and turbine installations

- Power generation
- Ship building
- Coffee
- Chemical