KOSO PARCOL

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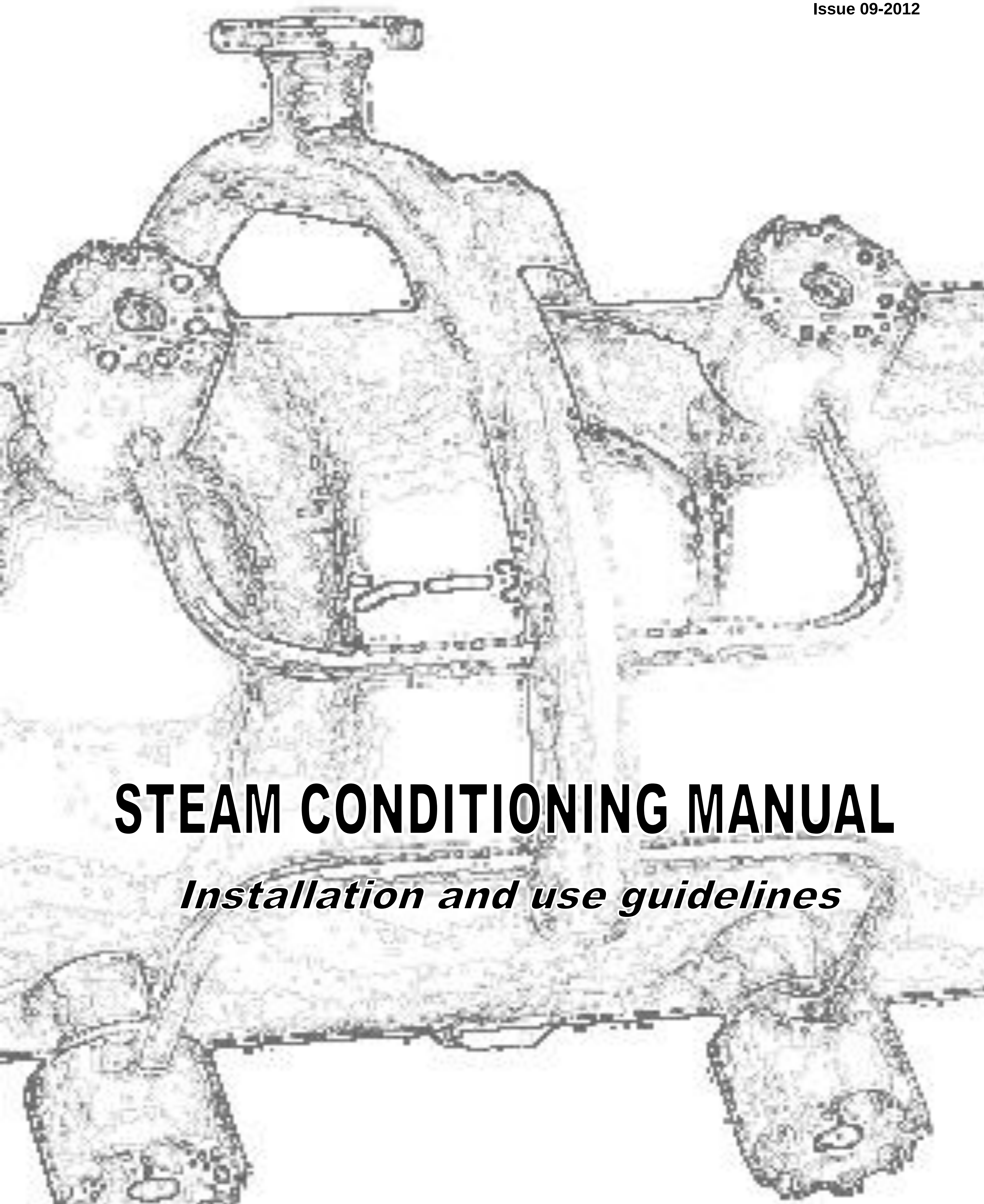


STEAM CONDITIONING MANUAL

Installation and use guidelines

SUMMARY

Parcol documents dealing with desuperheating:

- NTG 76/670 Enthalpic control systems
- NTG 76/674 Installation of variable area steam desuperheaters
- NTG 76/675 1-5800 series control valves with internal injection
- NTG 76/680 Acoustical treatment

0. INTRODUCTION

Recommendations outlined in this document are suitable both to integral desuperheating control valves 1-5000 and 1-9000 series, and, where applicable, to individual Parcol desuperheaters Spraysat 1-4442 and LF or LV 3-4000 series. Should these recommendations conflict with information provided by dimensional drawings, the latter will prevail on the content of this document.

1. SELECTION CRITERIA

1.1. DESUPERHEATING CONTROL SYSTEM SELECTION

Desuperheating control systems can be based on enthalpic calculation (feedforward loop) or on downstream steam temperature value (feedback loop).

1.1.1. Enthalpic calculation (feedforward control loop)

The first solution (feedforward loop) can not grant a precise temperature control due to process parameters (water/ steam pressure, temperature and flow) measuring errors. For these reasons desuperheating by enthalpic calculation is used for bypass to condenser applications or where saturated steam is required.
In any case injected desuperheating water flow is always higher than the calculated theoretical value to take into account measuring errors; for such a reason downstream pipeline must be self draining (for bypass to condenser applications) or condensate extraction system conveniently oversized.
For further details please refer to Parcol NTG 76/670 “Enthalpic control systems”.

1.1.2. Temperature control (feedback control loop)

The second solution (feedback loop) is always used when precise temperature control for desuperheated steam is required, typically for technical or industrial applications.
As outlined in this document, to allow a correct steam desuperheating the controlled temperature must be a few degrees over the downstream pressure saturated steam temperature.
Due to high response time of temperature controlled systems, particular attention must be paid to PID parameters setting. Being usually optimised proportional gain value very low and derivative parameter excluded, in case of sudden upstream steam temperature or flow variations, the implementation of a feedforward algorithm based on main involved process variables is usually suggested in order to avoid excessive deviations from required value of controlled temperature during transients.

1.2. DESUPERHEATER TYPOLOGY SELECTION

For a proper desuperheater typology selection it is necessary to take into account many parameters:

- desuperheated steam required characteristics:
  - maximum steam flow to be desuperheated;
  - controlled temperature accuracy;
  - system required turndown;
- process parameters:
  - superheated steam, desuperheated steam and desuperheating water:
    - temperature;
    - pressure;
- piping layout restrictions:
  - steam pipe diameter;
  - straight upstream and downstream length.

According to process parameters, it is possible to calculate the desuperheater Cv range, the steam velocity at maximum and minimum steam flow and, consequently, the system turndown.

At this point it is possible to select desuperheater typology through diagrams of figures 1, 2 and 3 together with pipe size and maximum applicable pressure drop limitations reported in Table 1.

For a correct desuperheater selection and installation, all limitations and recommendations reported in this document must be taken into account.

Table 1 – Maximum pressure drops and minimum steam pipe installation diameter for Parcol desuperheaters.

Desuperheater type		**Water to steam Max Δp** - bar	**Steam pipe min diameter** [2]
3-4500 – LF	fixed area nozzle probe design	No limitation [1]	1.½" ÷ 6"
3-4110 – LVP **3-4120 – LVM**	variable area nozzle probe design variable area multiple nozzle	No limitation [1]	4" ÷ 12"
3-4210 – LVA **3-4220 – LVAM**	steam-assisted nozzle, probe design steam-assisted multiple nozzle	No limitation [1]	8" ÷ 14"
1-4442 – Spraysat	multiple nozzle control valve	60 bar	6" ÷ 20"

[1] By installing an appropriate control valve. Maximum pressure drop across the nozzle = 30 bar.

[2] Minimum diameter depends on selected desuperheater flow capacity and size. Please refer to desuperheater bulletin for further details.

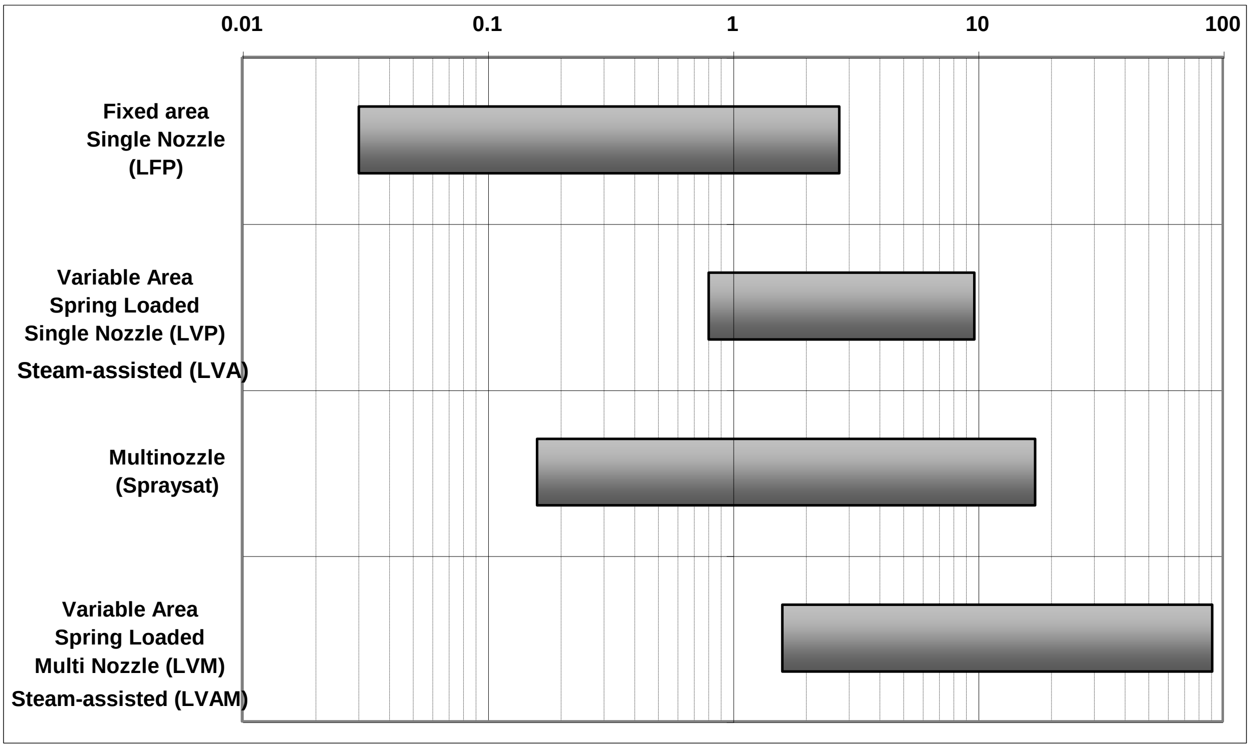


Fig. 1 - Parcol desuperheaters maximum flow capacities - gpm

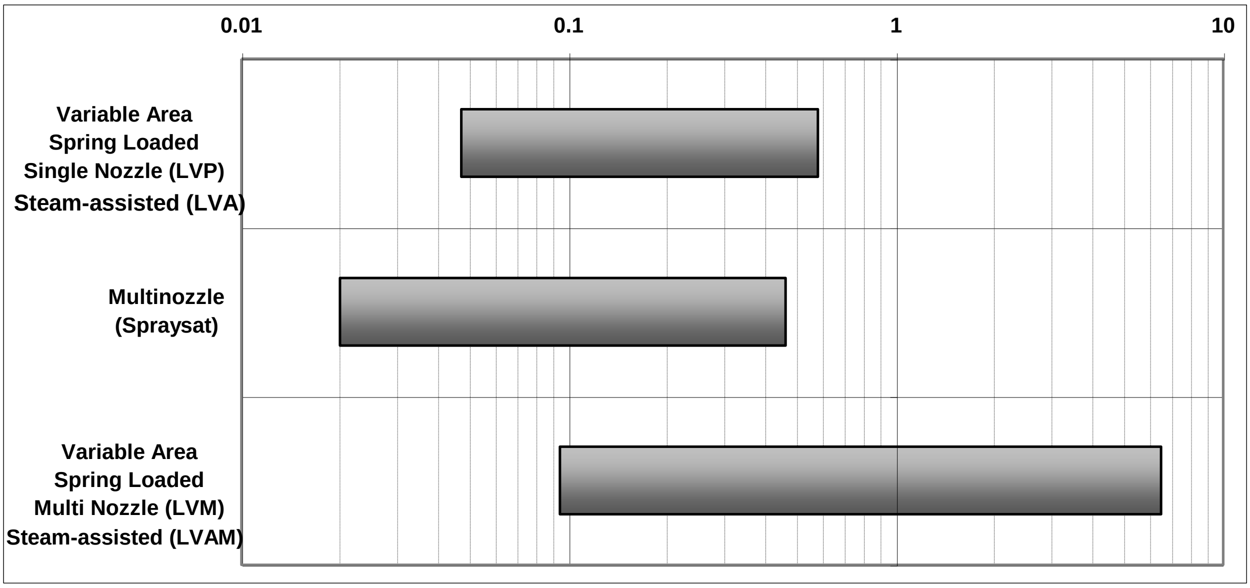


Fig. 2 - Parcol desuperheaters minimum controllable capacities – gpm

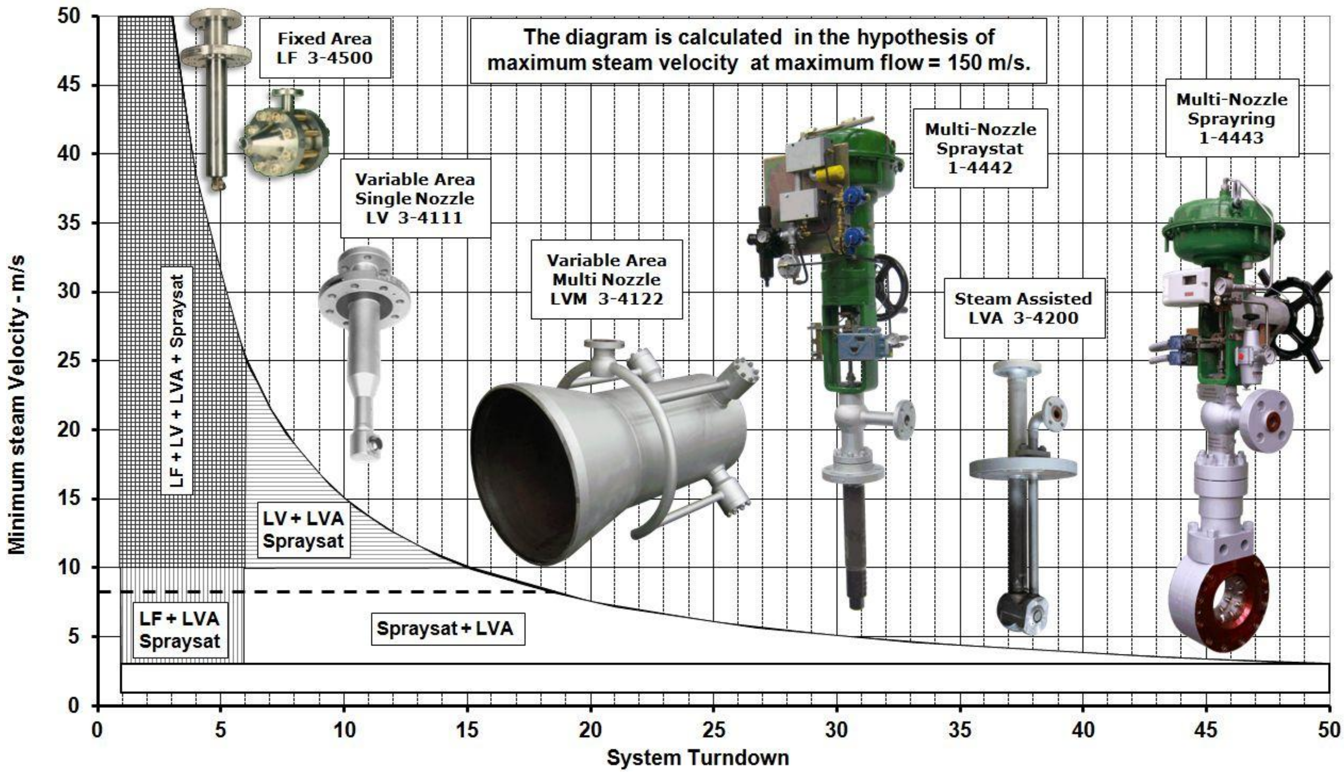


Fig. 3 - Parcol desuperheaters application range according to minimum steam velocity and system turndown.

Note: LVA nozzles (steam-assisted atomizer) can be used over the whole diagram area although its application with steam velocity over 10 m/s is not strictly required: the quality of water atomization is optimal also with other type, non-assisted, nozzles.

2. PIPING CONFIGURATION

2.1. UPSTREAM PIPING

Where two or more conditioning control valves are branched from the same header, some measures must be taken to prevent flow instability due to pressure resonance in inlet lines.

As shown in Fig. 4 the branches are tolerated provided they are designed with different runs.

The straight pipe without disturbances installed upstream the control valve must be longer than 6 times the inlet diameter of body including reducer, as shown in Fig. 5. This recommendation accounts for noise and vibration aspects more than flow rate prediction. Where elbow is unavoidable close to valve inlet, the minimum straight run upstream the valve depends on the radius of the elbow, and it should be 6 times DN1 for short radius (R ≤ 1,5·DN) and neglected (elbow connected directly to the body) for long radius elbow with R ≥ 5·DN. Interpolation is possible for intermediate figures.

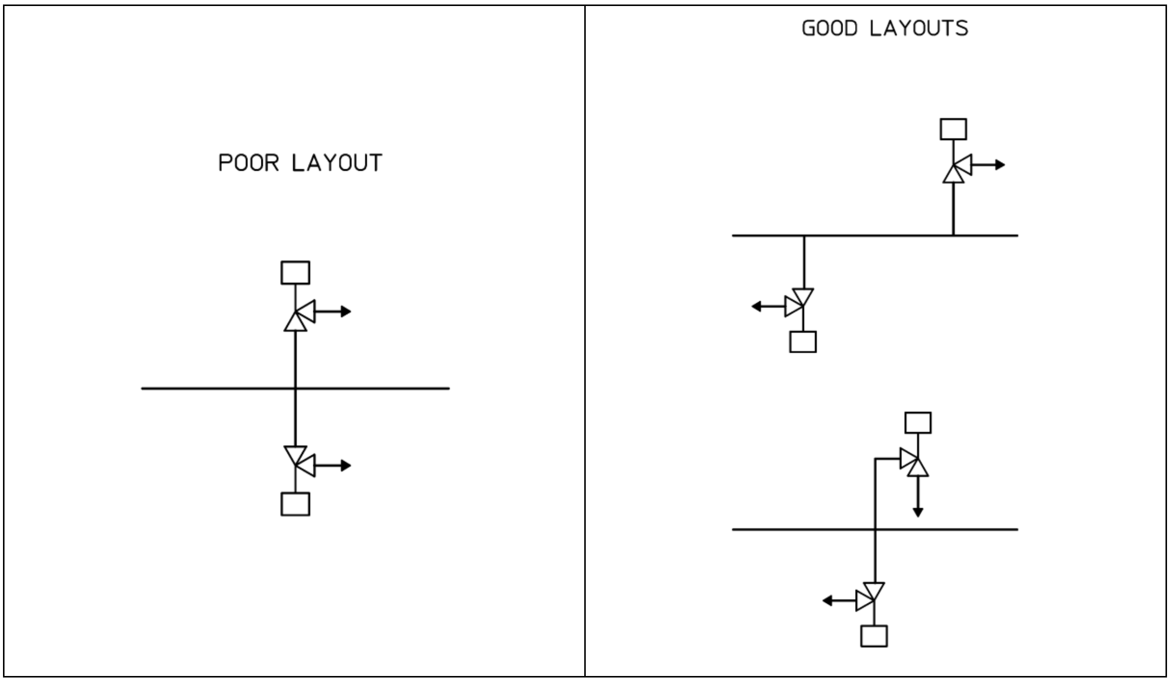


Fig. 4 – Layout examples with several desuperheating stations branched from a common header

For Parcol desuperheaters installed separately from reducing control valves the straight pipe without disturbances installed upstream the desuperheater must be longer than 5·D or 0.5 m where D is the average value between valve outlet diameter and downstream pipe diameter.

This minimum length can be conveniently reduced when flow straighteners (e.g. multihole plates) are provided.

When concentric reducers are installed the injection point must be at least 1·D downstream (D = minimum diameter of the reducer).

2.2. DOWNSTREAM PIPING

2.2.1. Layout

To prevent condensate collection on the downstream piping, avoid rising piping arrangement immediately downstream valve outlet: also when accurate draining is performed, accumulation of water excess in rising pipe may occur during start-up operations or for water supply malfunctions. Thus, installation of angle body type valves 1-5700 and 1-5600 with outlet upwards, is usually not recommended.
To reduce separation of atomized water from process steam, installation of measurement orifices and non-full bore valves downstream water injection is to be avoided up to temperature probe.
For similar reasons downstream pipe, before temperature probe, must be completely protected with suitable thermal insulation especially where on-off valves or expansion bellows are present.

2.2.2. Straight lengths

To prevent water/steam separation a minimum straight pipe length of 6 meters should be provided downstream the water injection section (the last one when two or more injection sections are provided). This applies also to variable diameter piping, provided the steam velocity requirements are fulfilled in any section (see Fig. 5).
Should special applications require longer straight runs they will be specified on technical documentation.

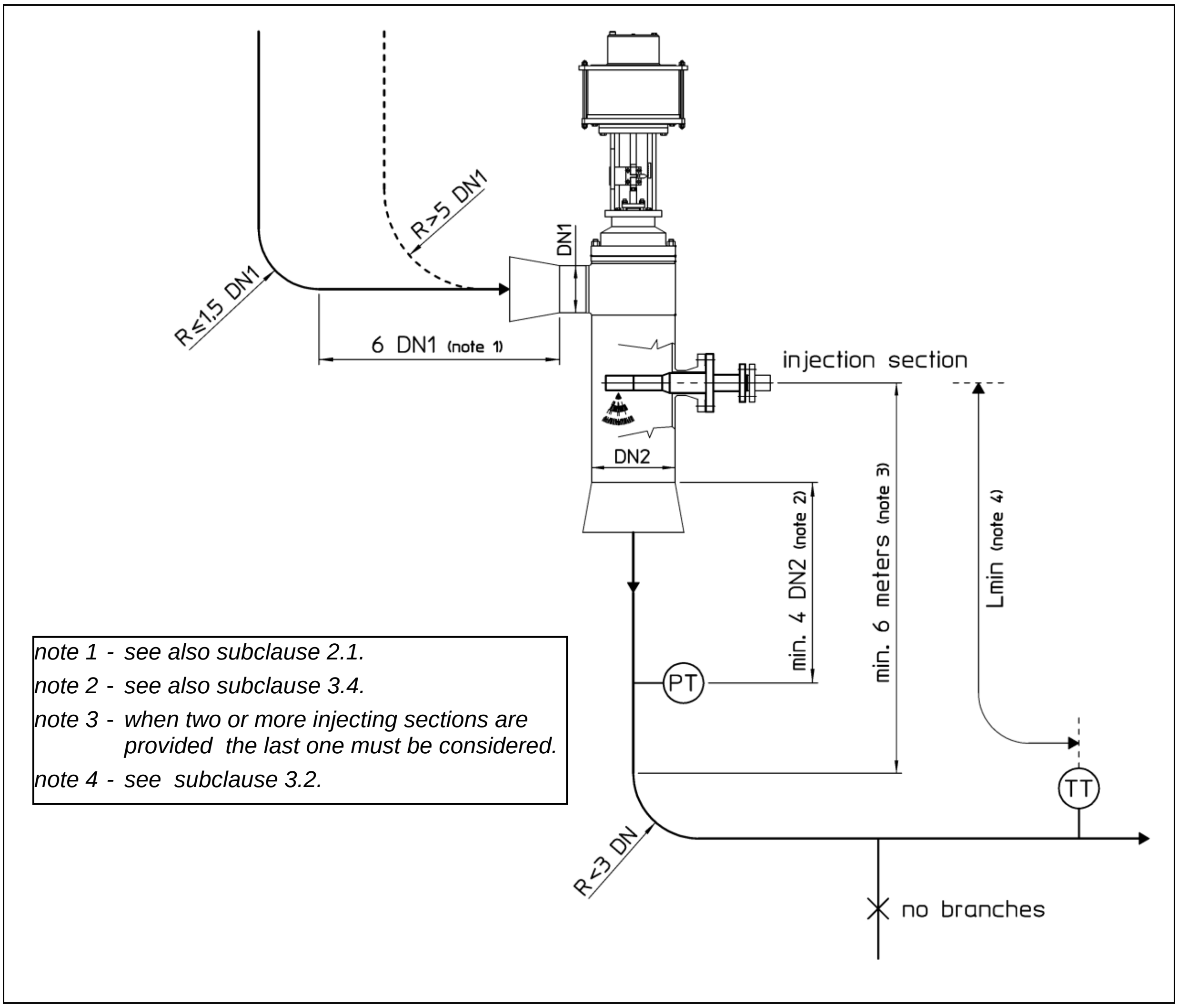


***Fig. 5** – Piping arrangement around the desuperheater – minimum distances and straight-lengths.*

2.2.3. Piping dimensions

Piping downstream desuperheaters must be sized to obtain a sufficient minimum velocity and consequently a satisfactory turbulence level on steam flow.
Such requirement is fulfilled when the pipe size is the same of outlet connection of desuperheating section, which is properly selected by Parcol. So, these recommendations apply to larger downstream piping sections connected to the outlet of control valve through an expander.
Typical minimum steam velocity values for PARCOL desuperheaters are listed in the following table; steam velocity is calculated on downstream section taking into account flow rate and steam conditions upstream water injection.
Due to the minimum required steam velocity the size of downstream piping must be checked at lowest steam flow rate according to the process turndown.
Minimum steam velocity values listed in Table 2 represent the minimum operating limits in the specific range of working conditions that allow the dragging of the water drops and must be fulfilled independently from the influence of other process characteristics.
Minimum steam velocity range reported for each nozzle type depends on several parameters such as: nozzle dimension, pipe diameter, nozzle pressure drop, steam pressure, injected water/superheated steam ratio, injected water temperature, desuperheated steam superheating.

Table 2 - Minimum steam velocities in the injection point and minimum water/steam pressure drops for different Parcol desuperheaters.

Type	Description	Minimum steam/water pressure drop	Minimum steam velocity (1)
3-4110 – LVP **3-4120 – LVM**	variable area nozzle, probe and multiple-nozzle design	Spring set + 0.5 *bar* (2)	10 ÷ 20 *m/s*
3-4500 – LF	fixed area nozzle probe design	0.5 ÷ 3 *bar* (3) (4)	8 ÷ 12 *m/s*
1-4442 – Spraysat (5)	multiple nozzle control valve	0.5 ÷ 3 *bar* (4)	8 ÷ 12 *m/s*
3-4210 – LVA **3-4220 – LVAM**	steam-assisted, variable area probe and multiple-nozzle design	Spring set + 0.5 *bar*	2 ÷ 3 *m/s*

(1) Reported values are valid for correct piping layout. Minimum values refer to optimum process condition, maximum values refer to not optimum process conditions.
For 1-4442 and 3-4500 series desuperheaters, minimum steam velocity depends on selected nozzles size too: higher nozzle dimensions require higher steam velocity. When **lowest Cv nozzles** are installed, minimum steam velocity can be reduced up to 3 m/s for the Cv range covered by such a nozzles.

(2) Minimum required value for correct water atomization. Lower values can be adopted for particular applications with high steam velocity and reduced performances.

(3) For fixed area nozzles, minimum pressure drop usually corresponds to minimum steam velocity condition while maximum pressure drop corresponds to maximum steam flow. For this reason, being maximum continuous nozzle pressure drop about 30 bar, the service rangeability of fixed orifice desuperheaters is usually between 3 and 8 depending on nozzle dimension.

(4) Minimum steam to water pressure drop (0.5 bar) is applicable for lowest nozzle sizes when steam velocity is over minimum requested value.

(5) Spraysat 1-4442 series desuperheaters are specially designed to warrant precise steam temperature control and maximum service rangeability. For this reason its use is recommended whenever steam conditioning for industrial applications is required.

When the pipe diameter does not allow to obtain the minimum recommended velocities, it is necessary to provide a reduced section in the area of injection or to apply a jacket of smaller diameter (liner) like the one commonly used for the thermal protection.
The minimum length of reduced section downstream the injection point should be stated according to the operating conditions and must be not less than 5÷6 meters.
To improve the distribution of steam flow an additional length of at least 3·DN but not less than 1 meter must be left upstream the injection point.

Table 3 reports an indication of the influence of single parameters on the minimum admissible steam velocity at the injection area.

Table 3 - Effect of increasing of process and installation layout parameters on minimum steam velocity at injection point.

Process or layout parameter	**Effect of parameter increasing on required minimum steam velocity**
Nozzle size	↑
Injection point and downstream pipe diameter	↓
Water to steam pressure drop	↓
Desuperheated steam pressure	↓
Water to superheated steam flow ratio	↑
Injected water to saturation temperature ΔT	↑
Desuperheated steam to saturated steam ΔT	↓

2.3. FIXED POINTS

The valve body can not be used as a piping fixed point.
Also outlet pipe should not be used for connecting piping to framework but, when this is unavoidable, measures must be taken to prevent the transmission of vibrations and noise through fixed points.

2.4. PIPING FORCES AND TORQUES

Parcol control valves are usually designed to assure the body housing is stiffer than the connected pipe. That means the section modulus of minimum body section is usually greater than that of the pipe either on inlet and outlet connections, therefore valve body is able to transmit stresses without suffering any unacceptable deformations that might impair the regular valve operation.
Where, for particular reasons, piping connections are significantly higher than valve body inlet/outlet pipe section modulus can be higher than valve body branches. In such a case maximum applicable forces and moments are reported on valve dimensional drawings.

3. TEMPERATURE AND PRESSURE SENSORS

3.1. MINIMUM TEMPERATURE

The minimum temperature for a correct desuperheating is 10 °C over the saturation steam temperature referred to downstream pressure. An appropriate temperature sensor distance from the injection point can reduce in some applications the minimum temperature for a correct desuperheating up to 6 °C over the saturation temperature.
The higher is the difference T_d - T_s the more efficient is the desuperheating process, with the same equipment and installation.

3.2. TEMPERATURE SENSOR DISTANCE

The minimum distance of the temperature sensor from the water injection point must not be lower than the maximum value between $L_{min(1)}$ and $L_{min(2)}$ <u>but in any case not lower than 12 meters.</u>

(1) $L_{\min(1)} \geq V \cdot x \cdot \alpha_{ts-tw}$

(2) $L_{\min(2)} \geq L_{\min\Delta T} \cdot \gamma_p$

where:

$L_{min(1)}$	:	minimum distance between injection point and temperature sensor to allow the water vaporization, taking into account the minimum required time for water heating and evaporation	*m*
$L_{min(2)}$	:	minimum distance between injection point and temperature sensor taking into account thermodynamic kinetics of vaporization and dragging of droplets	*m*
$L_{min\Delta T}$	:	uncorrected minimum distance of temperature sensor from injection point as a function of difference between desuperheated steam temperature and saturated steam temperature (Td-Ts) - see Fig. 6	*m*
V	:	steam velocity in downstream piping at superheated conditions	*m/s*
x	:	necessary time to get the full water evaporation. Use x = 0.2 where the Δp across the nozzle complies with the minimum recommended values	*s*
T_d-T_s	:	difference between requested final temperature T_d and saturated steam temperature T_S at downstream conditions	*°C*
T_s-T_w	:	difference between saturated steam temperature T_S at downstream conditions and the injected water temperature T_W	*°C*
γ_p	:	correction factor for steam pressure upstream the desuperheating section - see Fig. 7	- -
α_{Ts-Tw}	:	correction factor for water temperature versus the saturated steam temperature at downstream conditions - see Fig. 8	- -

To avoid excessive response time of the system, the distance between temperature sensor and the injection point must be lower than $V \cdot t_{MAX}$, where t_{MAX} (seconds) is the maximum allowable time for a stable process control.
For normal applications $t_{MAX} \cong 5$ seconds is assumed and the maximum distance of the temperature sensor with steam velocity = 20 m/s is 100 meters accordingly.

3.3. PIPING LAYOUT

- straight runs are described in clause 2.2.2
- in piping section running up to temperature sensor branches must be avoided

Isolating valves are not allowed in downstream piping as the rating of outlet section of control valve is generally lower than the inlet side. Different installations have to be discussed with Parcol before asking for an offer. This warning is particularly important for H.P. by-pass desuperheating groups due to the large ratings difference.

3.4. PRESSURE SENSOR

- pressure control downstream the valve is frequent in cogeneration applications where steam is used as a process fluid.
- as outlined in Fig. 2 pressure sensor should be located preferably in the straight run section at a distance from outlet of control valve at least 5 ÷ 6·DN2.

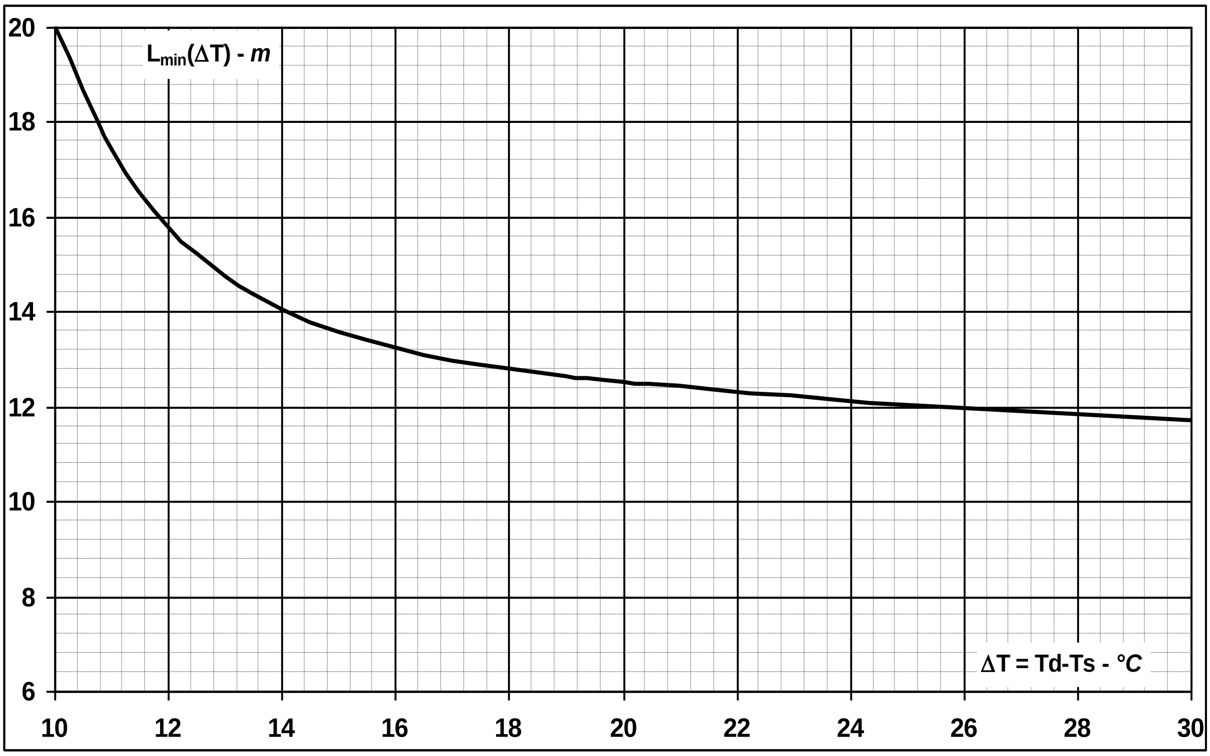


Fig. 6 – Minimum distance between temperature sensor and injection point

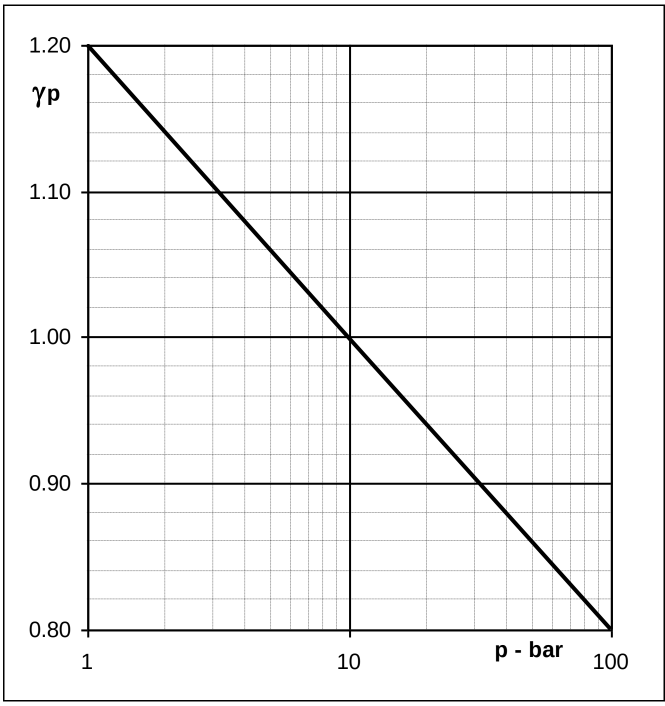


Fig. 7 – Correction factor for steam pressure

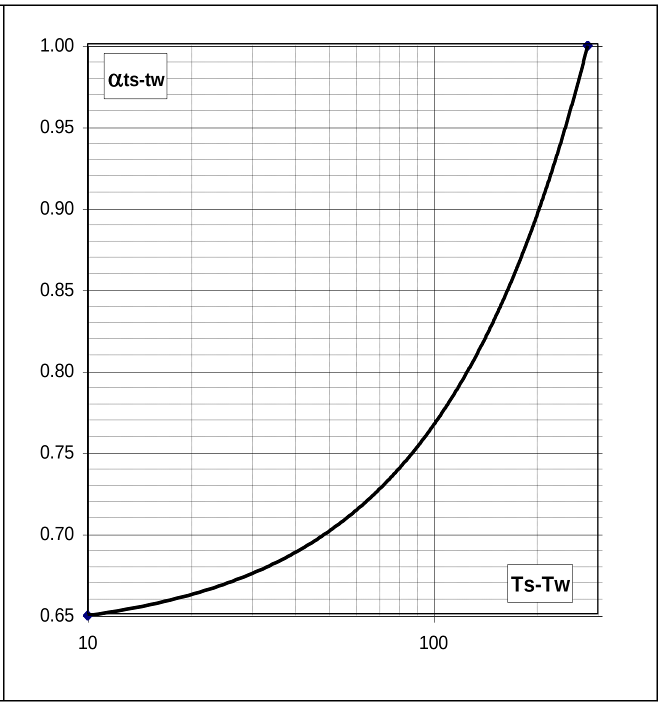


Fig. 8 – Correction factor for water temperature

4. DRAINS

The main sources of water inside the piping are the line condensate and the non-evaporated water injected through the desuperheating equipment.

Free water in steam piping can cause severe damages to pipelines due to dragging of water at very high steam velocities. Also, excessive vibrations and noise do easily occur.

At least, the measurement of steam temperature is strongly affected by the presence of free water.

Steam conditioning valves 1-5000 and 1-9000 series need to be protected from the damage caused by free water entering the body. Therefore drains are necessary upstream the valve.

For steam conditioning stations with temperature control, downstream steam pipelines must be water-free and it is essential to provide an accurate draining.

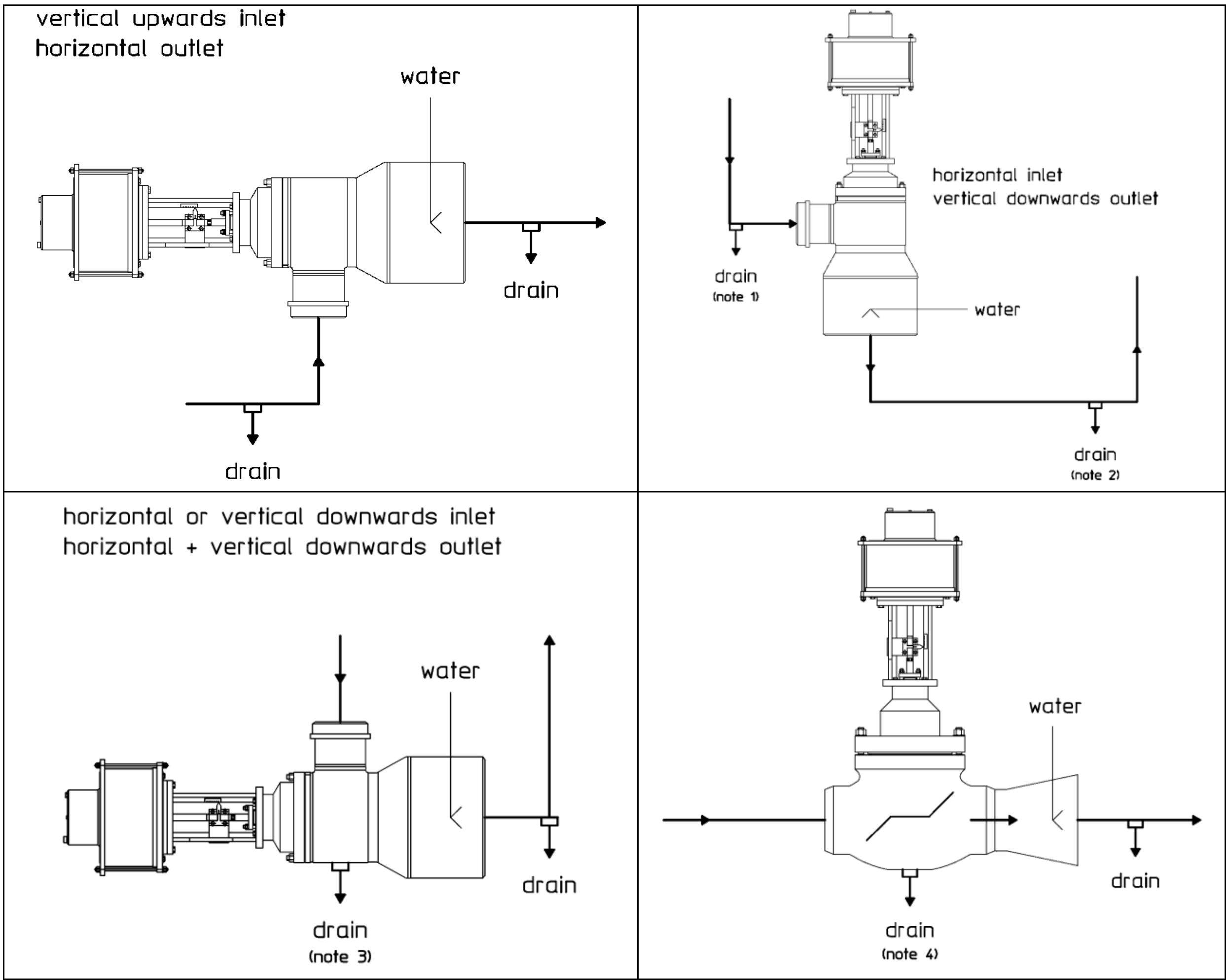
When water injection by enthalpic calculation is performed, typically for steam turbine bypass to condenser, no line drainage is usually required provided that downstream piping has the correct slope and the dumper is self-draining.

For some piping arrangements Fig. 9 shows where drains should be located.

Downstream line drains should be designed for a discharge capacity not lower than 10% to 15% of the maximum injected desuperheating water.

Drains must be located at the lowest point of pipe around the valve.

To guarantee a complete collection of water, the **drip-leg** (or drain-pot) directly welded to the pipe should have a diameter not less than the **half of pipe diameter**.



note 1 – recommended for any orientation of upstream piping.
note 2 – mandatory when downstream piping is going up or is not self-draining.
note 3 – for these arrangements the orientation of the drain connection provided on the valve body must be agreed with Parcol.
note 4 – mandatory for flow-to-close designs.

Fig. 9 – Drain arrangements around steam conditioning control valves

Fig. 10 - Angle body 1-5700 series desuperheating control valve

Fig. 11 - Straight-way globe type 1-5900 series desuperheating control valve

5. PREHEATING

Preheating of desuperheating control valve body is recommended depending on the following considerations:

- *valve location*
  By installing the valve above the header at a distance not exceeding 5 x DN about, where DN is the inlet valve diameter, an adequate pre-warming is generally guaranteed and preheating not necessary.
- *valve operation*
  The excessive thermal cycling of inlet section of valve body may occur when valve is normally operating in the closed position (typical for turbine by-pass applications).
  If an isolating valve is fitted upstream the control valve (not required for turbine applications), it must be assured that the isolation valve will be correctly opened for operational readiness of control valve.
- *thermal gradients*
  Provided the condensate is fully removed from the body, preheating is strongly recommended when temperature difference between live and saturated steam is over 200°C.
  Fig. 12 is a simple guide to select preheating as a function of live steam conditions.
  A remark: the continuous condensate draining can be considered as a preheating procedure having the scope to assure a body temperature not less than that of saturation.

In the case, according to above considerations, preheating is required, different ways to perform it can be selected depending on the type of valve and piping layout.

Here below the most usual solutions:

a) *recirculation of main steam*

An auxiliary line is derived from the live steam line and the steam is drawn through the valve body and recirculated to the same steam line.
To accomplish this arrangement the pressures of the take-off points (a) and (b) of by-pass must be sufficiently different (minimum 0.5 bar). To produce this pressure drop the head loss produced by steam flow through main pipeline is usually enough.
Due to the reduced diameter of auxiliary heating line, to avoid clogging due to condensate plug, steam flow should never been in opposite direction of line slope.
Fig. 13 reports a few examples of auxiliary line design for different steam piping layouts.

b) *adjustable by-pass valve or calibrated orifice (Fig. 14)*

The heating steam injection point is located in the downstream section of valve body and the differential pressure through the nozzle is the same of the main valve.
This solution is recommended when heating of downstream line is necessary and downstream injected steam can be recovered by the process.
For abovementioned reasons this solution is not recommended where the valve outlet is connected to the condenser.
When used in high pressure processes particular attention must be paid to the valve (d) which controls the heating flow because of the high involved Δp both in closed and open position. This valve can be replaced by a suitable calibrated orifice.
The sizing of preheating line and steam flow rate can be provided by Parcol and depends on the layout arrangement and valve type.

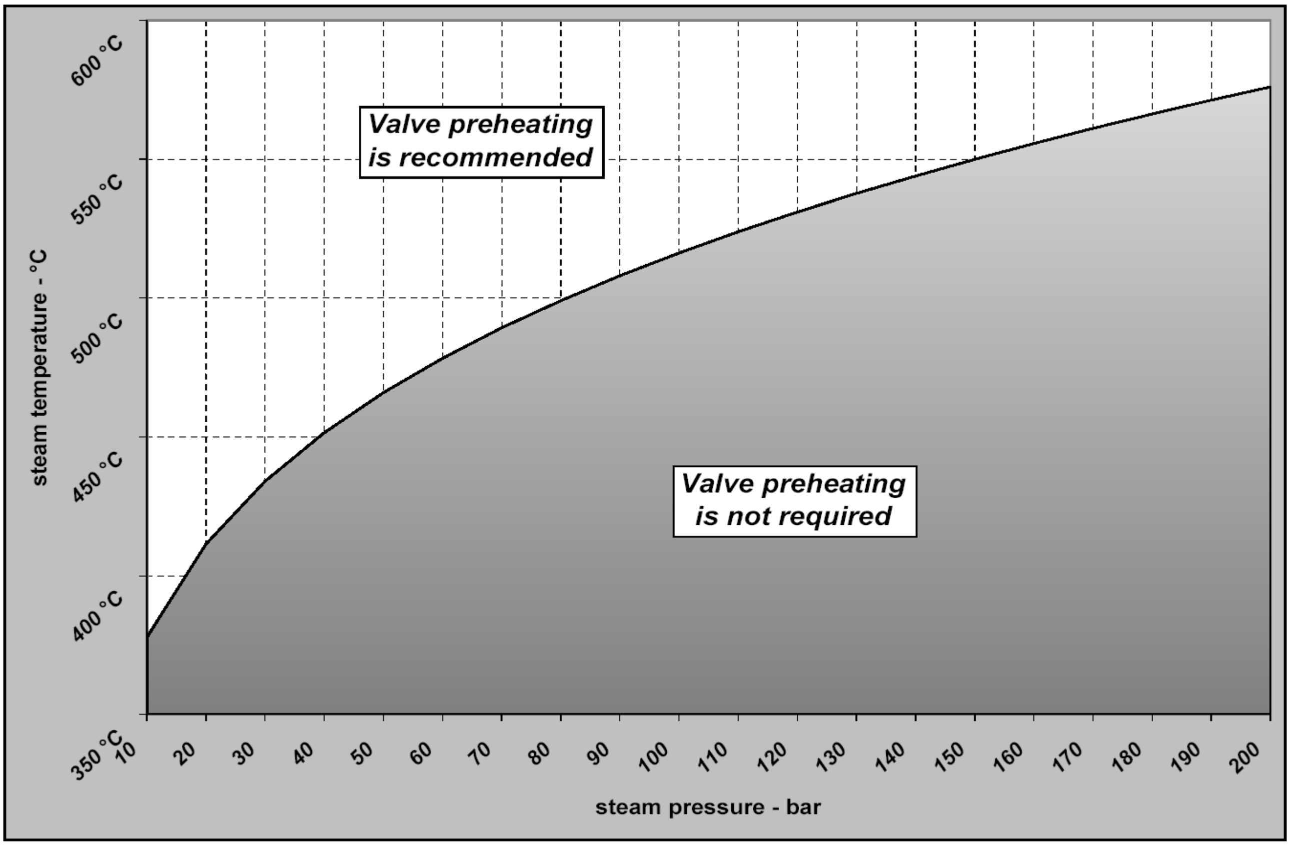


Fig. 12 – Guide to application of preheating of desuperheating control valve

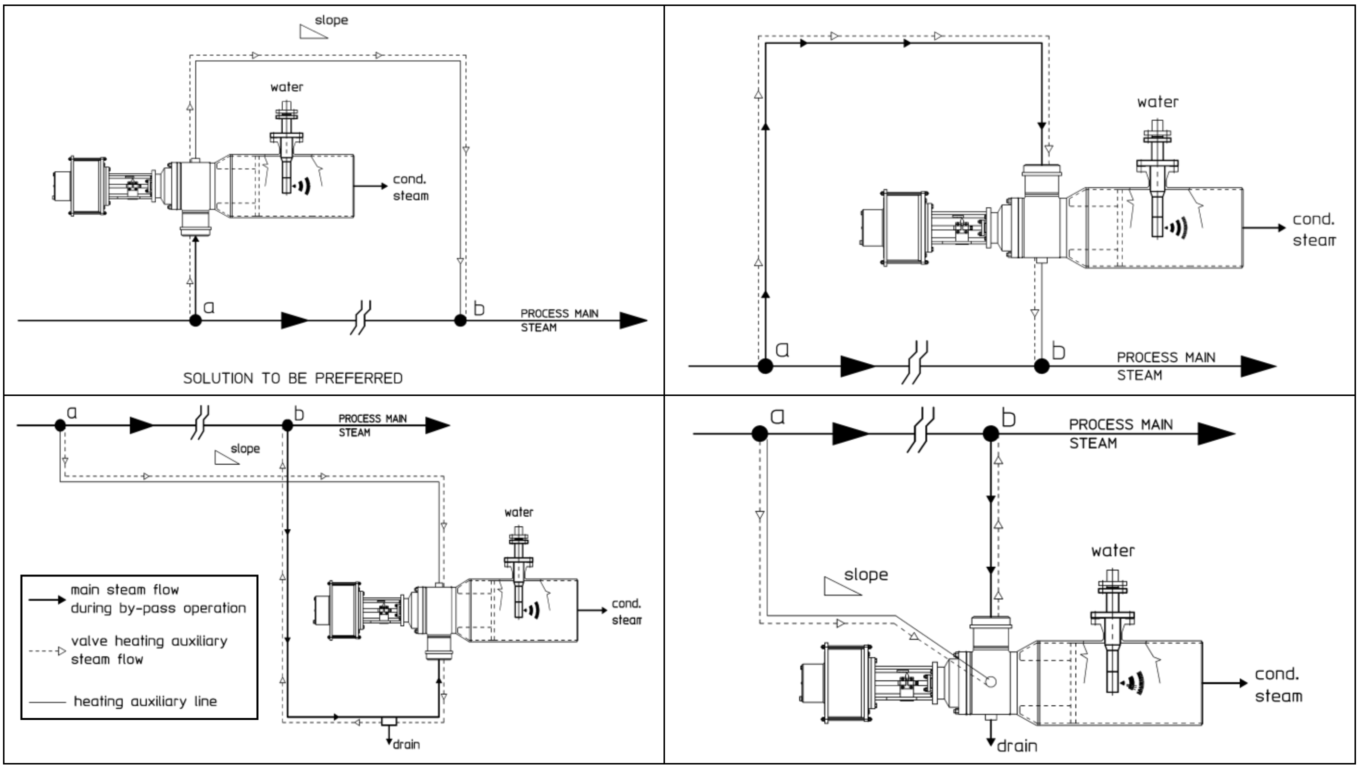
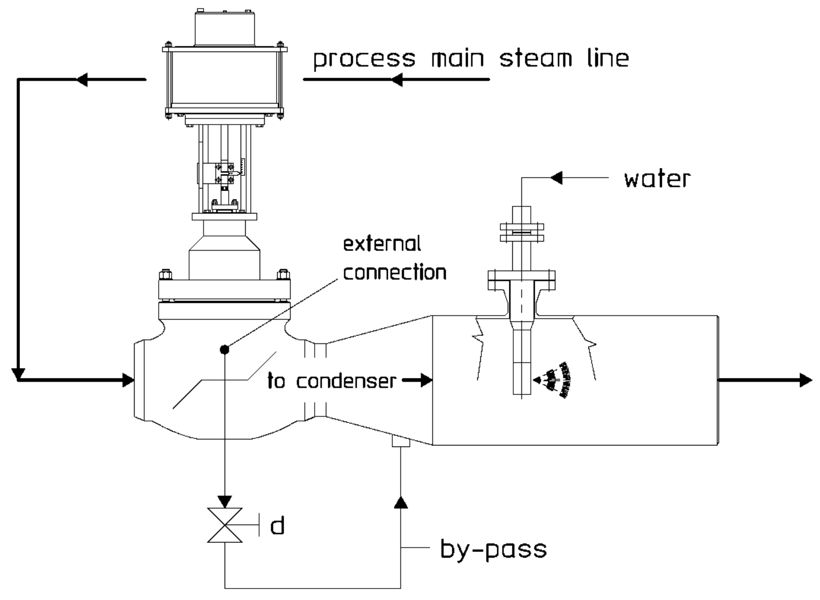
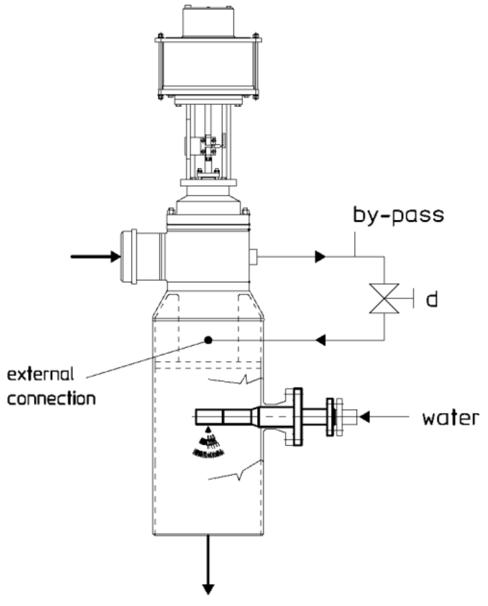


Fig. 13 - Upstream valve body and process line preheating performed by steam recirculation.



Straight way type control valve



Angle body type control valve

Fig. 14 - By-pass arrangements to preheat upstream and downstream valve body and process lines.

6. PROTECTION OF INJECTION POINT

Water dripping can cause the inside pipe surface to crack due to thermal shock.
Where not otherwise specified by the manufacturer of the desuperheater it is recommended to protect the piping against mechanical damages.
The following solutions are usually adopted:

- a protective jacket (liner) is installed *(usually applicable for steam pipe diameter over 6")*;
- a suitable thickness allowance is provided.

Installation of a liner is technically the best solution because it warrants the pressure containing parts protection in all working conditions. However, being the most expensive and constructively exacting solution, is usually adopted for continuous services when the difference between the superheated steam and the injected water is more than 250 °C.

For steam turbine bypass, unless otherwise specified by the customer, Parcol provides an additional wall thickness as pipe protection for at least 1.5·DN but not less than 0.5 m.

The additional thickness value, in addition to design value already inclusive of corrosion allowance, is:

$$s = 0.01 \cdot \Delta T \qquad \text{mm} \qquad (3)$$

where:

ΔT : $T_V - T_{H2O}$ - °C
T_V : steam temperature - °C
T_{H2O} : injected water temperature - °C

7. PROTECTION OF THERMOMETER WELL

The temperature sensor protection is recommended whenever the distance to the injection point is close to the minimum value and where considerable water amount is injected (desuperheating water flow rate over 25% of steam flow rate to be desuperheated).

Thermometer well protection is also recommended whenever one or more bends are present between water injection point and temperature sensor.
Such a layout in fact can produce separation of atomized water generating droplets that can hit thermometer well affecting measured temperature value.

Minimum upstream piping length shall be not less than 6 DN.

The protection may be manufactured as shown in Fig. 15 and its purpose is to avoid sensor wetting by not evaporated water.

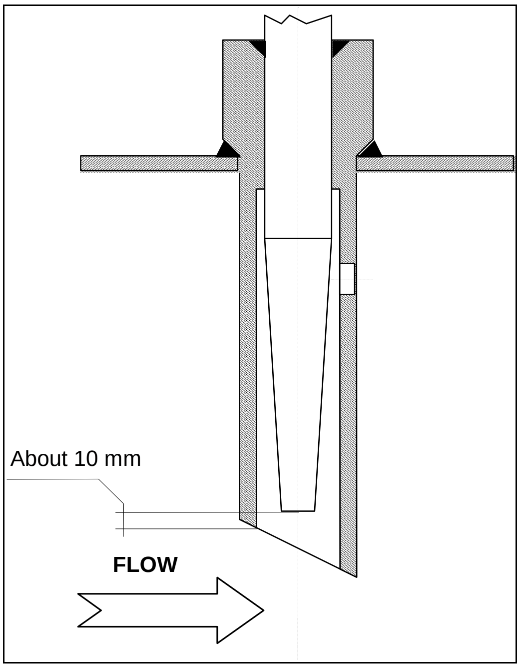


Fig. 15 – Typical design of thermometer well protection

8. NOISE

8.1. PREDICTION

The prediction of noise produced by a desuperheating control valve with downstream water injection is based on IEC 60534-8-3 standard equations.

8.2. ACOUSTIC INSULATION

Thermal insulation usually fitted on desuperheating valves and adjacent piping is an effective means to reduce noise produced by valve, depending on layout of downstream piping. This benefit is especially important for by-pass control valves to condenser where limited length of piping can be conveniently subjected to acoustical treatment.
More details on this matter are included in Parcol documentation NTG 76/680.

9. BLOW-OUT

Unless otherwise specified by mounting instructions, the valve disassembly before welding into the piping is not strictly necessary, however the upstream piping must be cleaned and free from any solid particles, for this reason blow-out must be carried out after welding of the valve body into the piping.

Where valve upstream piping shall be cleaned by blow-out after welding, the valve must be disassembled by removing all internal parts, except seat ring when welded to the body.

Body blow-through can not generally be performed when welded-in downstream silencers are provided. For exceptions to this rule please consult PARCOL engineering department.

After welding, a blowing device must be fitted inside the body as outlined in Fig. 16; the blowing device must be welded to exhaust chimney.

Check the cleaning of inside body cavity before reassembly, especially with non self-draining body shapes (ex. 1-5900 series).

Pay attention do not exceed with the steam used for the blow-out the maximum pressure and temperature limits specified in the technical documents.

PARCOL blowing devices allow for a long steam discharge with no danger for the seating surfaces of the valve.

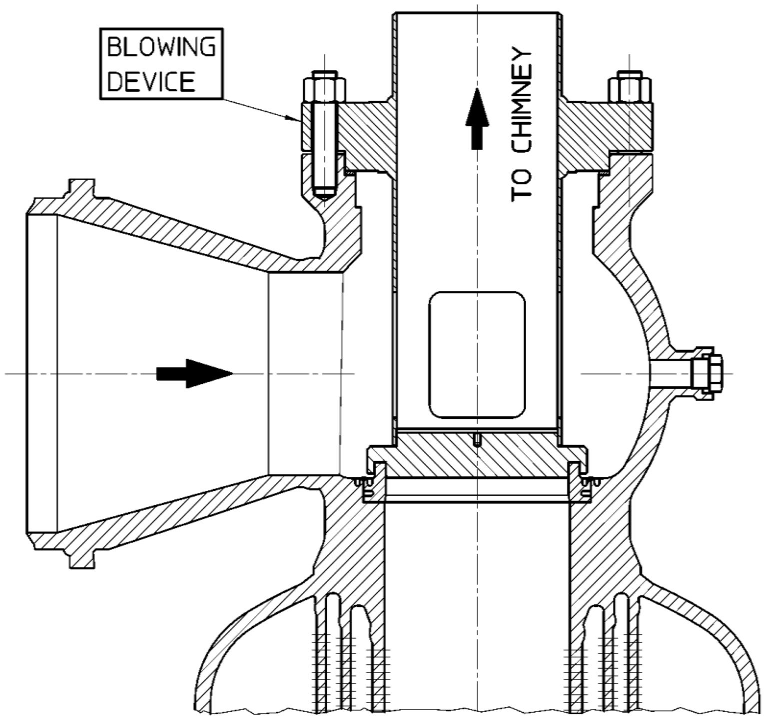


Fig. 16 – Upstream piping blow-out device with seat protection.

10. CLEANLINESS

Throughout assembling operations actuator and valve should be protected to prevent any dirt, dust or foreign matter from entering the valve and actuator.
We recommend to treat all parts with an appropriate agent in the event of long dwelling time between installation and start-up.
When hydraulic actuators are provided, the oil connections must be kept carefully closed. In this case control units and other electric devices must be installed just before start-up operations.

11. LIFETIME CONSIDERATIONS

The operating service which this type valves are intended to, frequently shows many changes of pressure and temperature, making critical the fatigue resistance of valve body.

Unless otherwise requested these PARCOL valves are designed according to TRD 301 criteria in order to obtain the following performances:

- maximum cold start-up : 2.000
- maximum corresponding combined cycles (hot startup) : 10.000
- maximum allowed temperature gradient : 2 K/min

For extreme design temperatures (above 545 °C) the 9% Cr steel (SA 217 C12A, SA 182 F91) is normally used for the construction of body and, in this case, the calculation can lead to allowable temperature change rates up to 5 K/min or better.

Where longer lifetime is requested, the use of 9% Cr steel, or equivalent, is mandatory to guarantee an acceptable value of temperature change rate.