Notes on adjustment procedures

COSTER

Tecnologie Elettroniche

1. COSTER guarantees, in accordance with the law, that its products are free of malfunctions and defects. Any malfunctions and/or defects must be reported in writing to COSTER within eight days of their detection, by registered mail with return receipt or by certified email, or the client will forfeit any warranty rights.

2. COSTER in any case guarantees the correct functioning of its products for a period of 3 (three) years following the year of manufacture indicated on each device, with the exception of products listed in Point 3 below, for which the warranty is 2 (two) years from the date of initial operation. The client must report the malfunction within 30 days of its detection, or the client will forfeit any warranty rights. All warranty liabilities are discharged six months from detection.

3. **For the following products, correct functioning as per the Point above is covered by warranty for a period of 2 (two) years from the date of initial operation: metering and enclosed control modules, energy integrators, flow meters, all components of the Wireless Thermshare except the GSM modem (if included).**

4. COSTER, during the period covered by warranty, will repair, and when this is not possible, replace, the products confirmed as being marred by defects or malfunctions. In any case, the choice of whether to repair or replace the products will be totally at COSTER's discretion.

5. Work covered by warranty to be carried out in the Coster laboratories is free of charge. The cost of all external technical assistance work will be charged to the Client. Expenses will be charged in the amount and in the manner decided in each case by Coster.

6. The warranty is not valid.:

a) if payment of invoices is not made within the terms agreed;

b) if the devices have been tampered with, without authorisation

c) if devices have been used in ways not compatible with the performance features indicated in the product's Technical Specifications;

d) if the original plaques have in any case been modified, removed or replaced;

e) if, in case of complaints, the Client has not suspended installation of the material the complaint is about.

7. Coster does not guarantee the suitability of its products for particular uses if not to the extent that such characteristics have been explicitly agreed in writing in the contract or documents referred to, to this end, in the contract;

8. Coster does not guarantee the correspondence of its products to particular standards and regulations in force in the Client's country;

e-mail: **info@coster.eu**

Technical Support e-mail: **assistenza@coster.eu**

General

Time constant (ts)

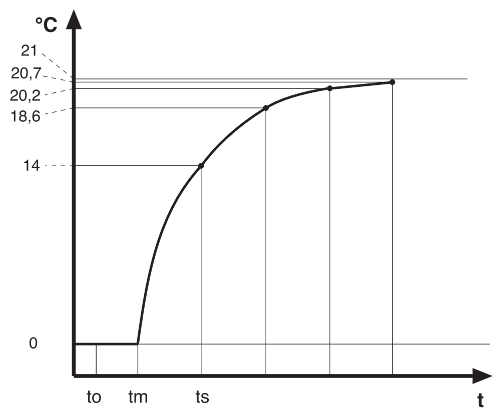
The effect which is obtained, following a modification of the desired value (e.g. ambient temperature = adjusted value), is never immediate.

This setting is determined by the "Time constant", i.e. the time necessary to recover 2/3 of the total variation (e.g. of the ambient temperature).
The same time (another "Time constant") will be necessary to recover 2/3 of the remaining third of the total variation, and so on.

Example:

Immersing a thermometer which indicates 0°C in a bowl containing water maintained at the constant temperature of 21°C and checking with a stopwatch the time which passes until the thermometer indicates 14°C (i.e. the time necessary to recover 2/3 of the 21°C). This time represents the time constant (ts) of the thermometer in question.

We now know that a similar time must pass until the thermometer indicates approx. 18.6°C (i.e. recovers 2/3 of the remaining 7°C), and so on. After 5 time constants approx. 99.3% of the total variation is recovered (in practice, the difference is considered to be recovered after 4 time constants).



t	Time
°C	Unit of measurement of physical quantity
ts	Time constant
tm	Tead time (start of measurement)
tm	Start of variation

Fig. 1.
Representation of time constant

When the value of the time constant, e.g. 10 seconds, is indicated in the technical specifications of the measurement sensors, we know that this is the time needed to measure 2/3 of the variation or difference which has occurred.

The time constant depends on the material, weight and the element used for the measurement. Consequently, it is specific for the model of for that manufacturer and it differs, in general, for the models of other manufacturers.

The time constant is found in all the measurement sensors of any physical quantity (temperature, humidity, pressure, etc.) and also in the components of the systems (heating appliances, etc.).

In our field of activities it is important to have sensors with different time constants depending on the planned use:

- Sensors with time constants of 10...25 minutes for measurement of the outside temperature of climate regulators and the like.

Reason = shorter times are not necessary (they can in fact be sources of regulation instability) since the outside temperature variations do not immediately influence the temperature of the rooms.

- Sensors with time constants of 20...40 seconds are used to measure the air supply temperature in ventilation and air conditioning systems.

Reason = the air temperature variations to modify the positions of the valve are immediate and consequently the temperature sensor must also react quickly.

- Sensors with time constants of 3...10 minutes are acceptable for the room temperature sensors (10 minutes with radiator heating or the like, 3 minutes with air systems).

Reason = time is needed for the room temperature to adapt to the new condition.

- Sensors with time constants of 5...10 seconds are necessary to measure the temperature of the domestic water of the users (mixture of hot water of the boiler or storage with cold water of the mains).

Reason = the regulation system is critical as it acts simultaneously with the temperature and flow rate variations.

Dead time (tm)

This is the time from the moment (to) the variation occurs to the start of the measurement (intervention of regulation system).

Considering a water speed of the system of 0.5 m/s:

- with sensor B1 the dead time is 1.5 m:0.5 m/s=3 sec. (negligible value);
- with sensor B2 the dead time is 30 m:0.5 m/s=60 sec. (excessive value for the regulation).

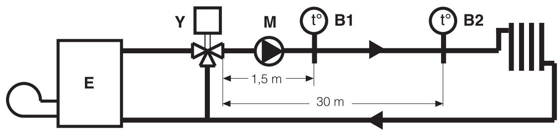


Fig. 2.
Example of dead time

Regolation precision

The regulation system in a plant must guarantee that the response to a variation of the controlled quantity has, during the transient, minimum oscillations of values and that the desired value (W) is subsequently restored.

Since the difficulties of the systems to be controlled are fixed (time constant “ts”, degree of difficulty “λ“ and transmission ratio “Ks”), it is necessary to adopt regulators with suitable regulation settings, select measurement sensors with time constants suitable for the system in question and locate them so as to exactly measure the quantity to be controlled.

Regulation settings

The conventional regulation settings are:
- Proportional setting **(P)**;
- Integral setting **(I)**;
- Proportional/integral setting **(PI)**);
- Derivative setting **(D)**;
- Proportional/integral/derivative setting **(PD)**;
- Proportional/integral/derivative setting **(PID)**.

Of these, the ones that are used in technological systems are: P - PI and exceptionally.

Proportional settings **(P)**

The actuator (motor-driven valve, servomotor for shutters, etc.) adopts positions proportional to the shift of the quantity from the desired value (W).

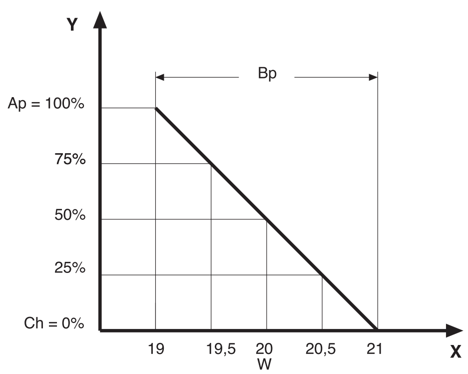
Consequently, the control signal (Y) of a proportional regulator depends, in the range of the proportional band, only on the value of the shift (Wx) of the quantity regulated from the desired value (W), that is to say, the control is directly proportional to the amplitude of the shift.

Parameters of proportional settings

Proportional band (Bp)

This represents the range of variation of the quantity regulated for the actuator to carry out the entire stroke from open to closed and vice versa.

Each position of the actuator in the proportional band corresponds to a single value, which is therefore easily identified, of the regulated quantity (temperature, humidity, etc.).



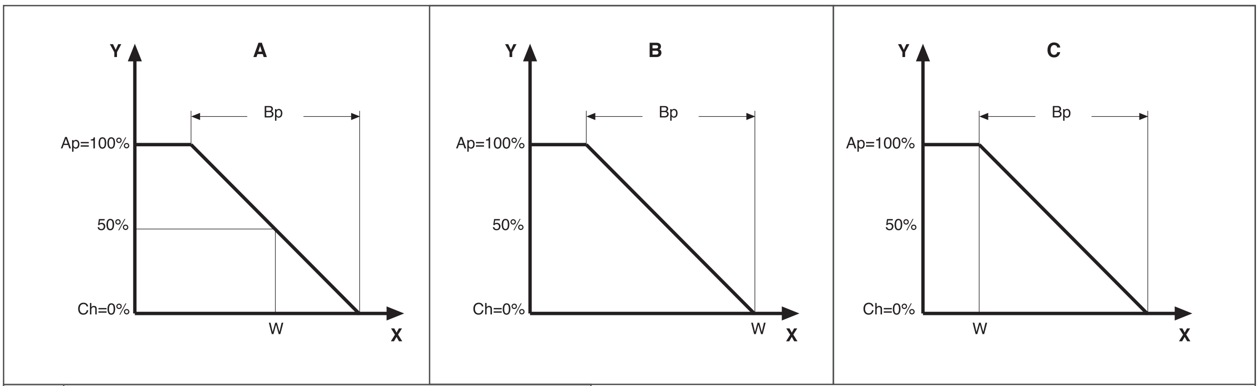
Y	Control signal
X	Actual measurement
W	Desired value
Bp	Proportional band (±1°C)
Ap	Full opening
Ch	Full closing

The desired value (W=20°C) only corresponds to the 50% (half stroke) position of the actuator; there are different temperature values in all the other positions.

Fig. 3.
Representation of a regulator with proportional band of ±1°C (Bp = 2°C total)

In the proportional regulators, depending on the use, the desired value (W) can be located in the range of the Bp:

- At the centre (A), i.e. at 50% = half stroke of the actuator, typical of regulators with 1 outlet;
- At an end (B), i.e. at 0% = actuator closed, typical of regulators with 2 outlets;
- At an end (C), i.e. at 100% = actuator open, for special uses (optimisation).



A	Desired value at centre
B	Desired value at increasing end
C	Desired value at decreasing end

Fig. 4.
Positions of the desired value (W) in the proportional band.

Permanent regulation shift (ΔWx)

The permanent regulation shift (ΔWx = X–W) is defined as all the values, in the proportional band range, different from the desired value (W).

Example:

If for a time (requested by the system) the load remains constant at the value corresponding to the valve open at 75% , see fig. 3, the temperature also remains constant at 19.5°C, so with a shift ΔWx of – 0.5°C (19.5 – 20 = – 0.5).

Amplification or sensitivity factor (K)

The amplification factor is the minimum value of variation of the measurement of the controlled quantity for which the actuator modifies its position; in other words, it is the sensitivity of the regulator.

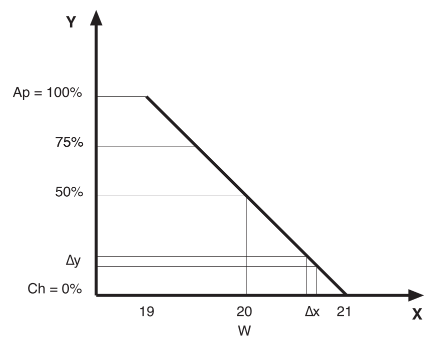
ΔX: minimum measurement modification value

(= $\frac{1}{20\%}$ of the Bp)

ΔY: minimum measurement modification value

(= $\frac{1}{20\%}$ of the total stroke)

Note. For microprocessor regulators, the factor “K” is replaced by the resolution + neutral zone, the value of which (fixed or adjustable) is not modified with the variation of the value of the proportional band (Bp), so the following only applies for analogue regulators.



ΔY=k x ΔX where:

Y	Control signal
X	Value of regulated quantity
k	Amplification factor of regulator

Fig. 5.
Proportional band of ±1°C with amplification factor k=20.

Esempio:

Considering a regulator with K = 20, this means that the minimum value of the control signal (Y) is 1/20 of the total stroke of the actuator (100% : 20 = 5%) corresponding to a similar 1/20 of variation of the controlled quantity (temperature, humidity, pressure, etc.) in the range of the proportional band.

The minimum control signal is constant, whatever value of Bp is set, as it depends on the design of the regulator (in this example, it is 5% of the total stroke of the actuator).

Vice versa, the absolute value of the modification of the quantity which originates the minimum control signal depends on the Bp set:

- with Bp of 2 °C the Δx = 0.1 °C (2 : 20);
- with Bp of 10 °C the Δx = 0.5 °C (10 : 20).

Considerations on proportional regulators

The proportional regulator:
- is called to respond to modifications of the controlled quantity or the desired value;
- is easy to use; the only parameter to set is Bp;
- regulates to the various values of the Bp set = permanent shift, only in an operating condition (position of the valve) corresponding to the desired value;
- In order to reduce the extent of the permanent shift, it is necessary to reduce the Bp;
- However, excessively small values of Bp can possibly transform the proportional modulating regulation in a 2 position (On-Off) operation.

Example:

SIf we consider a regulator for the control of the air supply temperature with K = 20 and we set a Bp of ± 0.25°C (total = 0.5°C) this means, as seen previously, that the valve would modify the position at every variation of = 0.025°C (0.5: 20 = 0.025°C), the regulation adopts an On-Off operation.

Note.

A regulation is considered to be stable if, when the minimum value of the quantity is modified, the actuator adopts the new position without any uncertainty. On the other hand, it is considered to be unstable when the actuator has difficulty in or is unable to position itself.

Starting up

Practical rule:

1) Set a Bp which is adequate for the system; approximately 1...2°C to regulate the ambient temperature, the collection or the mixing of the air, from 2...5°C for the supply of air for air conditioners or fan coils.

2) Act slowly on the calibration scale of the regulator positioning the actuator at the location of the desired value, in the range of the Bp (50%; 100% or 0%). The position identified is that of the value measured at that moment by the sensor, in general, different from that desired in the operation; for example, when putting into operation a room regulator, the temperature identified is 18°C, whilst the desired value during operation must be 21°C.

3) Provoke a small variation, modifying the identified value (18°C) and observing the reaction of the actuator:

- if after a short stroke it stops in a new position or at the most performs a couple of oscillations before positioning itself = stable operation, so Bp set correctly.

- repeat the previous operation modifying the temperature in the opposite direction, compared with the identified value.

vice versa :

- if the stroke is excessive, up to one of the ends = unstable operation, Bp is set too small

- progressively increase the Bp repeating the operations from point 3 at every new value, until a stable operation is obtained.

In other words, in the operation the actuator must make short strokes followed by stops.

Caution. An excessive increase of the Bp stabilises the regulation, but "highlights" the permanent shifts so operation for excessive periods of time at values much different to the desired value.
Consequently, if it is necessary to set a high value of Bp in order to stabilise the operation, it means that the proportional regulator is not suitable for the process.
One such case is the fixed point regulation of the temperature or relative humidity of the supply air for an air treatment machine...

Application

General

- Systems in which the regulated quantity is not subject to continuous and sudden variations (unstable load over time);

- Systems in which an operation is acceptable, under certain conditions, at values other than the desired value (permanent shift);

- Systems with large volumes (accumulators) or with constant flow rates.

Example:

- ambient regulation (temperature, relative humidity, etc.) in which the controlled quantity is not subject to sudden variations, allowing small proportional bands to be set (Bp) so with limited permanent shifts.

- regulation of the temperature of the secondary at constant flow rate with control of the motor-driven valve of the primary of a heat exchanger.

Non-recommemded applications

• For direct regulation to the users of domestic water, control of the mixing valve of the hot water of the storage or boiler with the cold water of the mains.

Reason: the measurement is affected by the variation of the temperature, but above all by the sudden and continuous modifications of the flow rate, due to discontinuous withdrawals over time.

• For regulation of the temperature, humidity, etc. of the supply air of an air conditioner or fan coil.

Reason: small modifications to the position of the valve immediately affect the air processed

Caution. Particular care is necessary in designing the motor-driven valves controlled by proportional regulator:
• Design the valves for the effective flow rate and head losses (see Section 5);
• Oversized valves (diameter greater than necessary) contribute to making the operation unstable;
• Use valves with shutters with equipercentage characteristics; the use of valves with linear characteristics such as sector valves, ball valves and the like is not recommended.

Integral setting (I)

The integral action acts on the actuator with speed proportional to the extent of the shift of the quantity from the desired value; there is not direct ratio between the shift and the position of the actuator, as in the case of the proportional action.

The ratio between the speed of the actuator and the shift (e.g. 1 mm/minute per 0.1°C) is defined as the integration ratio Ki.

The integral setting causes a control signal (Y) for the time there is the shift and progressively reduces until it no longer exists when the desired value is reached.

If the shift is not annulled, the actuator continues to operate over time until reaching one of the ends of its stroke.

The exclusively integral regulator is not used in our field of activities, as it is designed for the regulation of systems with a fast response and without inertia and with slow variations of the load.

On the contrary, the integral action combined with the proportional action results in a regulator which is commonly used.

Integral proportional regulators (PI)

The regulators (PI) use the advantages represented by the fast response of the proportional regulator, as a function of the shift value, with the independence from the load of the integral regulator.

In the presence of a modification of the controlled quantity:

• The proportional action intervenes immediately, the control signal of which modifies the position of the actuator on the basis of the shift value and the proportional band set.

• The proportional action is followed by the integral action which produces a control signal, repeating over time (Tn) the correction carried out by the proportional setting to annul the permanent shift from the desired value left from the proportional action.

The integral action ends when the set desired value is reached.

Integral regulator parameter

Integral time (Tn)

The integral time Tn is the time needed for the integral action to repeat a control signal of the same value as that performed immediately by the proportional action.

Note.

The behaviour of the regulator PI to a variation of the controlled quantity can be recognised by the first continuous control signal in the time (proportional action) and by the subsequent control pulses with a gradually reducing time with pauses of a gradually increasing time (integral action) with the reduction of the residual shift from the desired value.

Proportional/integral regulator parameters (PI)

There are two parameters in the PI regulators which affect the operation:

- Bp: proportional band
- Tn: Integral time

These parameters can have the following values:

- Fissi: definiti dal costruttore come in genere è per i regolatori climatici del riscaldamento
- Regolabili: nei regolatori destinati agli impianti di condizionamento, termoventilazione, ecc.

Starting up

Pratcal rule

Proceed as follows for the start up of regulators (PI) with Bp and Tn adjustable:

- Set the Tn to the maximum permitted value.
- Set the Bp to the value suitable for the system, following the instructions given for the proportional regulators (point 2.4).
- Progressively reduce the Tn until the system is stable, i.e. when a small modification of the desired value or the regulated quantity corresponds to small values of the control signal, that is, the desired value is quickly re-established.

Considerations.

- Bp and Tn less than optimum values: unstable regulation, control signal following a shift of excessive duration..
- With small Bp: the regulator operates as if it were only integral setting, that is, a long time is necessary to annul the permanent shift typical of the proportional component (in practice, the initial continuous control signal corresponding to the P is missing).
- With large Tn: the regulator tends to behave as it were only proportional (the time to correct the permanent shift is too long).

Derivative setting (D)

The derivative component produces a control signal on the basis of the speed and only when a shift of the quantity controlled from the desired value occurs.

Consequently, the derivative action is not active when there is not a variation of the measurement regardless of whether it is constant over time at a value different from the desired value.

In conclusion, its action is like an advanced control signal useful for neutralising the dead time but not able to annul the shift of the measurement.

Advantage.

- When the dead time is less than the response time of the controlled system, time constant which recovers 63.2% of the total variation of the quantity.

Not useful:

- With dead time ≥ of the system response time;
- Quantity with small variations over time.

Derivative setting parameter

Derivative time (Tv)

The derivative time, expressed in units of measurement in seconds or minutes (e.g. 2°C / s), is the time of duration of the action.

Application

The derivative time, expressed in units of measurement in seconds or minutes (e.g. 2°C / s), is the time of duration of the action.

On the other hand, the derivative operation in addition to the P and PI is important in the regulation of systems with long dead times.

Note.

The PD setting is not examined since it has no application in the regulation of technological systems.

Proportional/integral/derivative setting (PID)

The PID regulators use all three actions forming a control signal on the basis of the speed (D) of the shift, its amplitude (P) which continues over time (I) until the shift is annulled.

In the presence of a modification of the quantity:

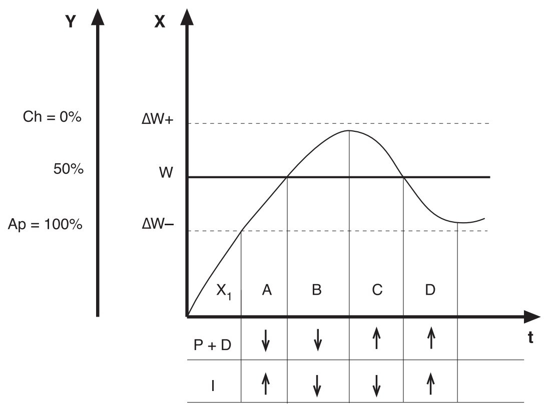
- The derivative action (D) firstly intervenes with an immediate signal progressively reducing over set time (Tv);
- The proportional action (P) then intervenes, the control signal of which is that relative to the set Bp, proportional to the shift;
- Lastly, there is the integral action (I) which in the time (Tn) produces a pause/impulse control signal until the desired value is re-established.

Note.

The regulation settings in the digital systems undergo modifications such as:

- limiting the integral action so that, if the shift persists over time, the actuator adopts the end positions.
- excluding the setting (I) when the set desired value is modified and in some cases limiting the proportional action.

Operation of a PID regulator



X	Value of the quantity (temperature, etc.)
X_1	Smallest measurement of the proportional band
Y	Control signal
W	Desired value (at the centre of the Bp)
ΔW-/ΔW+	Proportional band
t	Time
P	Proportional action
I	Integral action
D	Derivative action
↑	Tends to open
↓	Tends to close

Behaviour of the actions

X_1: value of the controlled measurement (physical quantity) less than the lower value of the proportional band, actuator open.

A: quantity increasing (e.g. temperature), P and D tend to close (the measurement is inside the proportional band); on the other hand, I tends to open until the quantity is less than the desired value (W).

B: quantity increasing compared with desired value (W); P, D and I act together operating in the direction of closure (I tends to close to annul the residual shift.

C: quantity reducing, P and D operate in the direction of opening; I tends to close until the quantity is greater than the desired value (W).

D: quantity reducing compared with the desired value (W); **P**, **D** and I act in the direction of opening (I tends to open if the quantity is less than the desired value).

Starting up

Set up the regulator just for proportional operation, setting the times Tn to the maximum and Tv to the minimum (excluding the two actions I and D) and setting a Bp to obtain a stable regulating condition.

Then reduce the Tn and the Tv increases taking into consideration that with:

• XP and/or Tn less than the optimum values = runstable regulation;

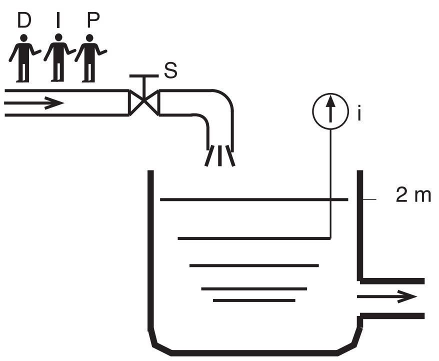
• Tv too low= sweak control signal when there is a shift of the controlled quantity, in practice derivative action almost nil (but still to be preferred to an excessive value of Tv);

• Tv t00 high = The regulation settings P, I, D can also be highlighted with an example such as that shown in Fig. A where the level of the tank is managed by three operators using the gate (S) and the level indicator tool (i).

Annexes.

Regulation settings

The regulation settings P, I, D can also be highlighted with an example such as that shown in Fig. A where the level of the tank is managed by three operators using the gate (S) and the level indicator tool (i).



P-I-D: Operators

S	Inlet gate
i	Level indicator
→	Fluid withdrawal

Fig. A.

The operations know:

• the value of the level to be maintained, which is assumed to be 2 m (= set or desired value);

• the total stroke, open/closed, of the gate (S), which is assumed to be 8 complete turns of the handwheel (= stroke of the motor-driven valve).

Proportional setting (P)

The level is controlled by an operator, who, by nature, is methodical and by experience knows that:

• for a reduction of the level of 0.1 m opens the gate (S) by 2 turns

so

• for a reduction of 0.2 m (twice the previous one) opens the gate by 4 turns, and so on.

Consequently, the gate will be fully open for a modification of 0.4 m of the level (= total range of proportional band).

The procedure is therefore:

• for a reduction of the level (= increase in load) measured by the variation of the index of the level indicator (=measurement sensor) of 0.1 m (= minimum measurable value)

• open the gate by 2 turns without considering the desired value.

From now and until a new variation of the level is noted, it remains in standby.

The operator stops the reduction in the level by introducing the same quantity which is withdrawn, but, inevitably, the level is less than the desired value by 2 metres (= permanent shift).

Due to the methodical nature, it is not essential to restore the level to the desired value; it is sufficient for the level to be stabilised at a value in the range of variation recommended by experience (= proportional band).

The operating procedure is the same as the regulator with the proportional setting (P):

• Moves the gate to the positions corresponding to the extent of the variation (= shift)

• Does not re-establish the desired value

• Accepts that the level persists over time to values different to the desired value, providing they are in a certain range (= proportional band).

Integral setting (I)

Let's imagine giving the same duty to an operator who is not very meticulous.

For a reduction of level indicated by the instrument, the gate starts to progressively open, slowing down with the reduction of the speed of movement of the index of the instrument (= speed of the actuator as a function of the shift). At a certain point the index stops (= volume introduced equal to that withdrawn), but the level will inevitably be less than the desired value..

This situation does not satisfy our operator. The operator is not an expert, so he/she continues to slowly open the gate until the index of the instrument positions itself on the desired value.

The operator now stops, but the level does not stop and continues to increase, obviously without there being a variation in the withdrawal, and the volume introduced is now greater than that withdrawn, so it exceeds the desired value causing the intervention of the operator to progressively close the gate.

It can be easily seen that when the level is restored to the desired value the gate will be closed more than necessary with the consequence that the level reduces further thereby requiring a new intervention to open the gate. This cycle repeats itself continuously in exactly the same way as a regulator with an exclusively integral setting where the control speed of the gate is proportional to the shift of the level from the desired value.

Derivative setting (D)

The control of the level of the tank is given to an operator with an energetic nature, but not very careful.

Following a sudden increase in the withdrawal, the operator immediately opens the gate exclusively on the assessment of the speed with which the level drops. The level indicator is observed and if variations in the index of the instrument are not noted, whatever the absolute value of the tank level, ... the operator rests.

The operator's work starts and ends in the time in which a variation of the index of the instrument is noted. If the level does not undergo modifications, even if the value stays different from the desired value, this does not cause concern for the operator who continues to rest.

Unfortunately for the operator, the rest does not last long since, in order to stop the reduction in level the gate has been opened for a flow rate greater than that withdrawn because of the delay in acquiring the measurement due to the dead time and time constant of the instrument (= reaction of controlled system).

Consequently, the operator is amazed to note that the level starts to increase forcing him/her to intervene to close the gate always and only on the basis of the speed of the increase.

Presumably, without a modification to the withdrawal (= constant withdrawal), it will have closed too much ... forcing a new opening of the gate.

This is all without being able to obtain the desired value and stabilise the system. In practice the work is of no use, however the energy is useful for neutralising the dead time (providing it is less than that of the process reaction), naturally combined with the two operators considered previously.

Proportional/derivative setting (PD)

Considering that none of the 3 operators considered are completely satisfactory, let's see whether combining them together is advantageous.

The first combination considered is that of giving the duty of maintaining the level of the tank to the two operators (P) and (D).

Al verificarsi della modifica del livello, l'operatore (D) interviene subito esaurendo la sua prestazione immediatamente impedendo un'ulteriore modifica del livello (per lui, come sappiamo, il valore prescritto non è una condizione imperativa).

Operator (P) then takes control of the situation, positioning the gate on the value (opening or closing) proportional to the extent of the shift.

The two combined actions result in:

• recovery of the dead time and of the general delays in the system by the intervention of operator (D);

but

• but it does not eliminate the permanent shift typical of the operating method by operator (P).

In conclusion, we have improved but only for certain situations which are unlikely to be found in heating and air conditioning systems.

Proportional/integral setting (PI)

In this case, the duties are given to the (P) and (I) operators.

When there is a modification to the level, the methodical operator (P) positions the gate in order to introduce or reduce a volume of water equal to that withdrawn ... end of the work. It is now the turn of the colleague (I), that knowing the set (or desired) value, and seeing that it is not at the desired level, intervenes on the gate (opening or closing) with a modification followed by a pause for reflection to check the result.

After this, if the modification is sufficient (which is never the case) ... he rests.

On the other hand, successive interventions are made to a progressively reducing extent and, vice versa, with increasing pause times as it comes near to the set (or desired) value.

The work of operator (I) develops over time and consists in a finishing to eliminate the shift left by the colleague. The two operators integrate perfectly; the setting (PI) is present in many regulators in both the civil and industrial field.

Proportional/integral/derivative setting (PID)

The method for managing the level differs from the previous one as follows:

- use of 3 operators
- the presence of the energetic operator (D)

With the immediate and fast intervention usually to a greater extent than that of the shift, the presence of operator (D) allows a recovery of the delay times in the acquisition of the measurement. This intervention relieves the work of the colleagues (P) and (I) which act afterwards as described in the previous subsection.

The action of operator (D) recovers, following a shift of the measurement, in times less than the set value, so it is suitable for circuits or systems with sudden load variations.

The only difficulty could be that of integrating the work of the 3 operators (= calibration of the regulator), if there is no agreement between the 3 ... there are no longer the advantages.

Regulating valves

General

The valves are identified on the basis of the constructional characteristics and their use, such as: valve body, internal shutter, type of movement, operating pressure, etc.

1. Subdivision of the valves according to the movement of the shutter:
- Sector valves (rotary movement);
- Ball valve (rotary movement);
- Shutter valve (alternating movement).

2. Subdivision of the valves according to the number of paths.

2-way valves:
- Butterfly valve;
- Ball valve;
- Single seat shutter valve;
- Double seat shutter valve.

3-way valves:
- Sector valve;
- Ball valve;
- Mixer shutter valves (2 inlets, 1 outlet)
- Diverter shutter valves (1 inlet, 2 outlets)

4-way valves:
- Sector valves;
- Shutter valve (it is actually a 3-way valve with incorporated bypass).

Shutter valve

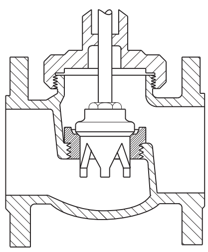


Fig. A.
Single seat valve

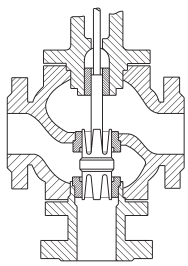


Fig. B.
3-way mixer valve

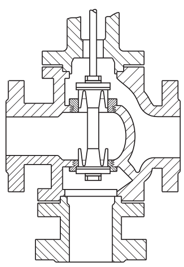


Fig. C.
3 way diverter valve

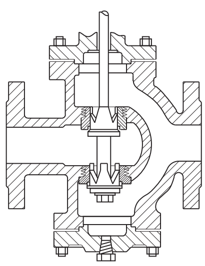


Fig. D.
Double seat valve

Sector valve

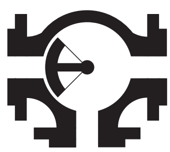


Fig. E.
3-way valve (mixer or diverter)

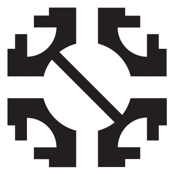
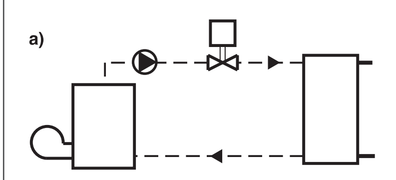


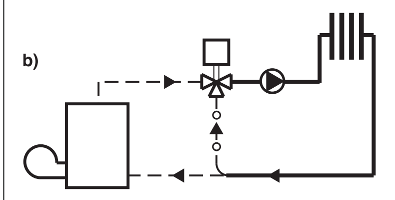
Fig. F.
4-way valve

Fig. 6.
Valve cross-section

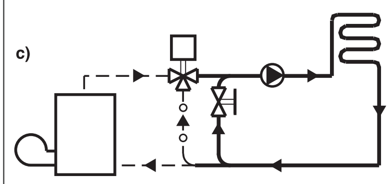
Dimensioning of the regulating valves



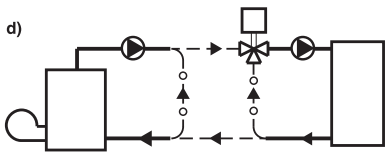
a. 2-way shutter valve for heat exchangers and batteries with a variable flow rate and constant temperature.



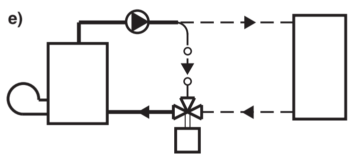
b. 3-way mixer regulating valve for heating systems with conventional heating appliances.



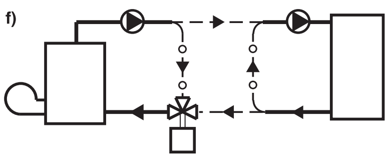
c. 3-way mixer regulating valve for heating systems with panels.



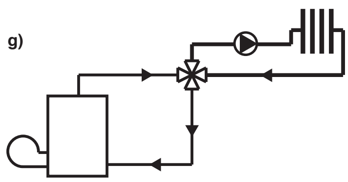
d. Injection system with 3-way mixer valve on the supply to the user and primary and secondary pump.



e. 3-way regulating valve (mounted on return) for heat exchangers and batteries with a variable flow rate and constant temperature



f. Injection system with 3-way mixer valve on the return of the primary circuit



g. 4-way regulating valve for heating systems with conventional heating appliances

———	Section of circuit with constant flow rate
— o —	Section of circuit with variable flow rate which does not concern the dimensioning of the regulating valve
– – –	Section of circuit with variable flow rate the head loss of which is that which the regulating valve fully open with the design flow must have

Fig. 7.
Systems highlighting the sections of circuits with variable flow rate which, affecting the valve regulating path must be considered when they are dimensioned.

Criteria to be considered when dimensioning

The regulating valve must be dimensioned so that the head losses of the regulating path fully open with the design flow rate must be at least equal to that of the hydraulic circuit section with a variable flow rate affected by the regulating path of the valve (fig. 7), which is an essential condition to obtain an authority (Pv) of the valve equal to 0.5.

Reason: the authority (Pv) must be greater than or equal to 0.5, obtained from the equation:

$$Pv = \frac{\Delta Pv}{\Delta Pv + \Delta Pc}$$

Δpv	Head losses with valve open with nominal design flow rate
Δpc	Head losses of the circuit section with variable flow rate

Note. The analysis of the dimensioning of the valves only concerns those with modulating control, as it is not significant for those with ON/OFF control and it can be easily of the same diameter as the pipe..

Data necessary for the dimensioning

The diameter of the regulating valve may be defined having:

- the flow rate and the head losses of the circuit section with variable flow rate;

or

- the power (or energy[1]), the head loss of the circuit section with variable flow rate and the difference of design temperature between supply and return.

The valve diameter is obtained with the above data

- from the specific diagrams for both the water and the steam;
- afrom the mathematical relationships (more precise method)

There are two diagrams available:

- specific, normally indicated on the technical schedules, for each series of valves determining directly the diameter as a function of the head loss;
- general, both for water and steam where, depending on the head loss, the Kvs is determined and then the diameter of the value is determined, with the tables.

From the mathematical relationships

- **For water.**

Hot (maximum 110°C) and cold (without antifreeze).

$$Kvs = \frac{Q}{\sqrt{\frac{\Delta pv}{10}}} \text{ which gives } \Delta pv = \frac{Q^2}{Kvs^2} \times 10 \text{ and } Q = Kvs \times \sqrt{\frac{\Delta pv}{10}}$$

where:

- Q= m³/h (design flow rate with valve open);
- Δpv= m of water column (head loss with regulating path open.

(1) The power can be obtained by knowing the flow rate:

- **For water it is necessary to know the difference in supply/return temperature from which the flow rate Q = P/Δt derives** $Q = \frac{P}{\Delta t}$

where

- Q = l/h or m³/h (design flow rate)
- P = kW or kcal/h (design power or energy)
- Δt = °C (temperature difference)

Note.
With P expressed in kcal or kcal/h the flow rate (Q) in l/h is obtained.
With P in kW or kWh a number is obtained which multiplied by 860 expresses the flow rate (Q) in l/h.

• **For satured steam**.

$$Kvs = \frac{Q}{22.4 \times \sqrt{\Delta pv \times P2}} \text{ and therefore } \Delta pv = \frac{Q^2}{(22.4 \times Kvs)^2 \times P2} \text{ e } Q = 22.4 \times Kvs \times \sqrt{\Delta pv \times P2}$$

where:

• Q= kg/h (nominal flow rate);

• Δpv= bar (head loss with valve open)(2);

• P2= bar (absolute pressure of the steam at outlet from valve)(3)

• **For steam, the flow rate**(4) can be determined knowing the power with the following equation: $Q = P \times 1.6$ or $Q = \frac{Px860}{540}$

where:
• Q = kg/h (nominal flow rate).
• P = kW (nominal power).
• 1.6 = average calorific power of a Kg of steam.

(2) The head loss to be assumed should be agreed with the designer; when this is not possible, adopt a value equal to 30% - 50% of the steam pressure at the inlet (and always less than the critical head loss, the value of which is indicated in the diagrams).

(3) Absolute pressure = relative pressure + 1 bar (the relative pressure is that normally indicated and corresponds to the operating pressure, i.e. the pressure read on the pressure gauge of the steam generator).

(4) When the power (or energy) is known instead of the flow rate.

Practical valve dimensioning examples

Note.
In the following examples the head losses considered take into consideration values acquired in practice, that is, the effective head loss of the circuit section with variable flow rate is not considered.

Caution. When the dimensioning of the regulating valves is carried out by us, the head loss must be approved by the consultant or installer, so it must be indicated in the quotations and referred to during negotiations.
Reason: it is not always possible to know the head loss of the circuit section with variable flow rate which is needed to dimension the diameter of the valve, so the customer might not agree with our choice..

Valves of centralised heating systems with radiators, convectors, etc. with climatic regulation

3 and 4-way sector valves, see circuits "b" and "g" of Fig. 7.

Practical rule, when the design data are not known:
• With supply pipes to the system up to DN 80 = valves with the same diameters as the pipes;
• With supply pipes to the system greater than DN 80 = valves with diameters smaller than that of the pipes.

Reasons:
• For valve construction reasons the head loss must be kept to values of between 0.4...0.6 m of water column with maximum limit of 0.8 m of water column.;
• The influence of the circuit section with variable flow rate (boiler) is normally negligible compared with the section with constant flow rate (user);
• The system curve (see subsection 4.1) tends to be linear;
• The supply temperature to the heating appliances varies as a function of the external temperatures according to the climatic curve set in the regulator, the characteristic of which complies with that of the emission of heat of the heating appliances.

Summing up:
• The only purpose of the valve is to mix the hot water coming from the boiler with the cooler water returning from the heating system.

Questo è il suo unico compito, perciò la valvola può essere un "chiodo" ... basta che non si blocchi, viceversa il regolatore deve essere "furbo".

Dimensioning when in possession of design data

The valve diameter may be identified in 2 ways depending on the data available:

1. Known case:
• the flow rate Q in l/h or m^3/h.

2. Known case:
• the power P in kW or kcal;
or
• the energy E in kWh or kcal/h and the difference in design temperature Δt between the supply and return of the heating system.

Solution of Case 1 directly using diagram 1 of the sector valves

(see below)

Data available, flow rate of 37,000 l/h (= 37 m³/h).

• Solution with the use of the diagram (flow rate – head loss) for the sector valves.

Procedure.

• Draw a vertical line from the value of 37 m3/h on the scale of the flow rates (X-axis) until meeting the horizontal line drawn from the scale of the head losses from 3 to 6 kPa (Y-axis).
• The meeting points with the sloping lines indicate the value of the kvs.

For the 37 m³/h the kvs are considered with acceptable head losses (see subsection "Valves of the centralised heating systems ..." page 19):
• Kvs 240 results in a head loss of 2.5 kPa (0.25 m of water column)).
• Kvs 170 results in a head loss of 4.8 kPa (0.48 m of water column).

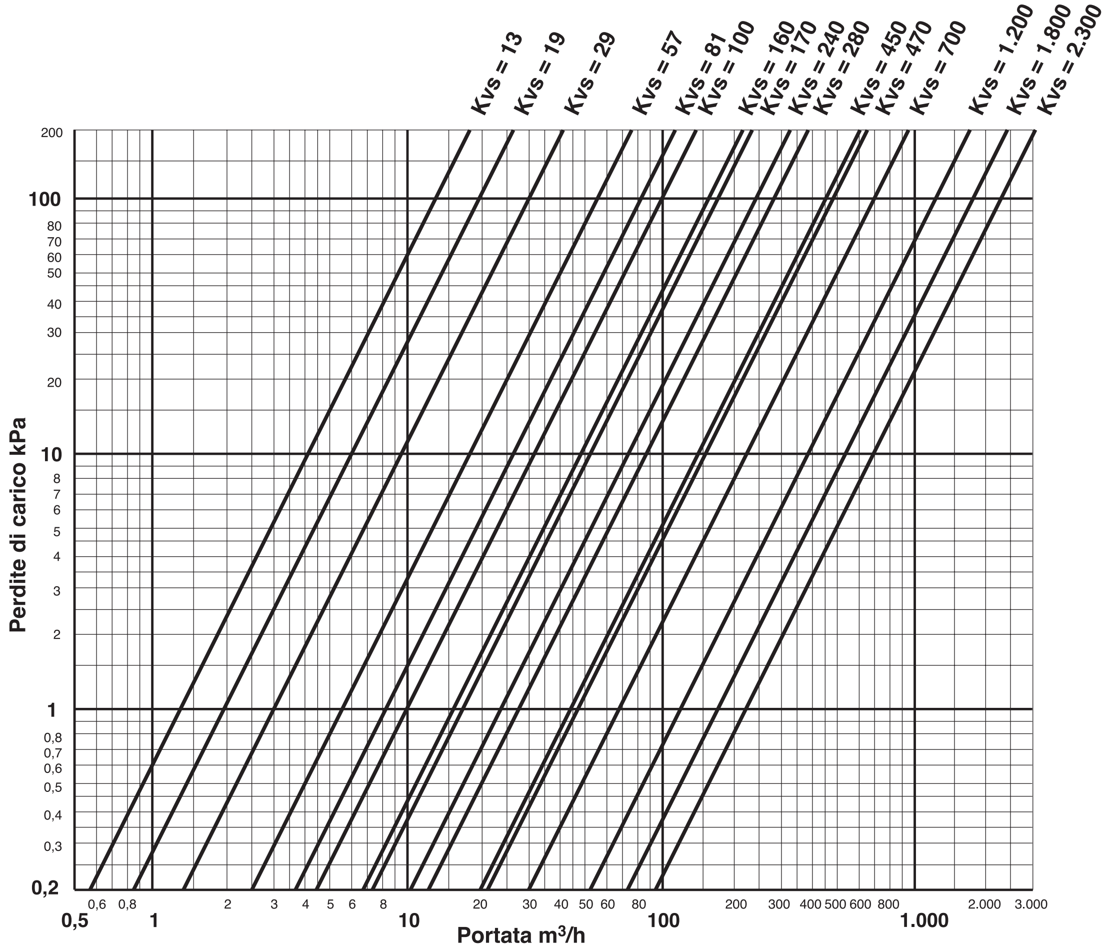


Diagram 1.
General diagram for water of the 3 or 4-way butterfly and sector valves.

General diagram for water of the 3 or 4-way butterfly and sector valves

www.coster.eu

2012 versione 00

D3

made in Italy

COSTER

CONTROLLI
TEMPERATURA
ENERGIA

COSTER TECNOLOGIE ELETTRONICHE S.p.A.

Head Office and Sales
via San G.B. De La Salle, 4/a 20132 Milano
Tel. +39 02 2722121 Fax +39 02 2593645
info@coster.eu www.coster.eu

Orders receiver.
Fax +39 02 27221239
ricevimento.ordini@coster.eu

Regional office Central & South.
via S. Longanesi, 14 00146 Roma
Tel. +39 06 5573330 Fax +39 06 5566517
centrosud@coster.eu

Shipping - Warehouse - Logistic
via Gen. Treboldi, 190/192 25048 - Edolo (BS)
Tel. +39 0364 773202 Tel. +39 0364 773217
spedizioni@coster.eu

Branch in UK.
COSTER T.E. UK Branch
5 Shaftesbury Street South, Sir Francis Ley Industrial
Park - Derby DE23 8YH
Tel. +44 (0) 1332 200555 Fax +44 (0) 1332 204181
ukbranch@coster.info