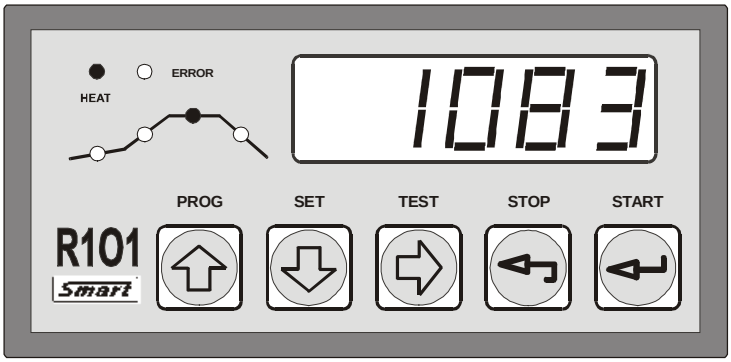
DESCRIPTION AND OPERATING INSTRUCTIONS FOR R101 CONTROLLER

The **R101** Programmable Temperature Controller from the **SMART Brno** company has been designed to control temperature in electric furnaces and heating systems by using contactors or solid state relays (SSR). The controller controls temperature in a furnace by using simple programs. Each program contains one or two controlled segments of increase in temperature to the required value, a segment for holding this temperature for a set period, and the controlled or uncontrolled end of program. The programs can be activated with a set delay.

The controller allows to control two auxiliary outputs using a program. Each output may be assigned with some of the following functions: the switch over of the heating of a furnace "star-triangle", and the control of the auxiliary servo-mechanism, such as a servo-flap, alarm, or fan.



The front panel of the R101 programmable controller

The controller provides, with its software and despite its simplicity, a number of options for the quality control of heating, such as PID controls with adjustable coefficients and adjustable switching frequency. It allows to delay the start of heating by as long as 99 hours.

The required temperatures and holding time are set by using a 5-key foil keypad with a tactual response in a simple dialog mode. Temperature and time are indicated in a five-digit LED display. The course of a cycle is displayed by four LEDs, another two LEDs indicate the switched-on heating (the yellow one) and a possible failure (the red one).

The control itself of the controller is divided into four levels:

1. Operator level – only allows to start or end the current programs.
2. Technological level – allows to perform operations with programs and set control parameters (technological process control).
3. Service level – allows to carry out such adjustments of the controller that essentially influence its behaviour.
4. Manufacturer level – allows to calibrate the controller.

Access to the individual levels, with the exception of the control level, is protected by password, which prevents an unauthorized person from changing the controller's setting. In the technological level, the use of password may be enabled or disabled.

The **R101** controller succeeds the series of the known **TEMPREG 100** temperature controllers from the **SMART Brno** company. It is, however, additionally equipped with the temperature compensation of the cold end of thermocouple and the modular concept of its new software provides easier adjustments of the control program for various applications.

I. BASIC PARAMETERS OF CONTROLLER

Input:
- voltage - thermocouples S, K, N,J, C, voltage 0 to 25mV or 0 to 50mV
- current - 0 to 20mA (includes a range from 4 to 20mA)
- resistance - 0 to 300Ω (e.g: Pt100 or resistance measuring)
  - 0 to 3,000Ω (e.g.: Pt500, Pt1000, Ni1000 or resistance measuring)
  - 0 to 30,000Ω (e.g.: Ni10000 or resistance measuring)

  The resistance input is connected by two conductors, the compensation of the line resistance is controlled by the controller software.

The input type (voltage, 0-300Ω resistance, 0-3,000Ω resistance, 0-30,000Ω resistance, or current) must be included in an order.

Output:
- switch contact of 230V/2A relay (S1)
- change-over contact of 230V/2A relay (S2)
- change-over contact of 230V/2A relay (S3)
- output 15V/15mA (on/off mode) for solid state relays control

Options:
- setting of required temperature in the range from
  - 0 to 900 °C for J thermocouple
  - 0 to 1300 °C for K thermocouple
  - 0 to 1600 °C for S thermocouple
  - 0 to 2300 °C for C thermocouple
  - -200 to 500 °C for Pt100, Pt500, Pt1000
  - -50 to 200 °C for Ni1000, Ni5000, Ni10000
- as many as 16 program cycles (10 free ones + 6 "lockable“ ones) may be stored
- operations with the current program – adjustment, reading and overwriting
- operations with a program and setting the controller may be performed during control process
- adjustment of the control mode
- possible selection of input sensor from the keypad
- adjustment of control parameters may be performed during program run
- delayed start of a program with the maximum delay of 99 hours 59 minutes

Protect:
- all set parameters remain unchanged even after a power failure
- individual settings and operations with a program may be protected by password
- error detection of the input sensor
- error detection of program and the setting of the controller
- setting of the maximum temperature of the system (the maximum value of the controlled factor) after whose exceed the protection contractor and the heating are switched off
- setting of the maximum period of a controlled cycle
- record of the maximum/minimum temperature during a cycle

Detect:
- interruption of the input sensor
- exceeding of the maximum temperature set by the manufacturer of the furnace
- exceeding of the controlled temperature of program
- leaving the permitted band above and below the temperature curve
- errors in the adjustment of controlled parameters
- faulty adjustment of the input sensor
- faulty adjustment of the maximum temperature
- program errors

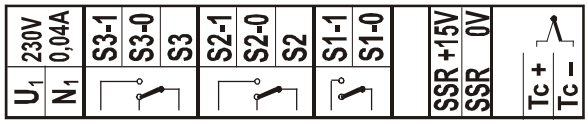
Voltage: 230V/3VA, 50 to 60Hz
Dimensions: 96x48x130mm (w/h/d), installation opening 92x43mm
Coverage: IP 50, IP 54 if required
Weight: 450g

II. INSTALLATION OF CONTROLLER

The controller is fixed to the switchboard in such a way that it is inserted in the prepared installation opening with dimensions of 92x43mm and fixed with two clamps that are put, by using a screwdriver, on two pairs of fixing pins located on the sides of the controller.

Connection of power supply, control of contactors or solid state relays, control of auxiliary servo-mechanisms, and connection of the input sensor are performed by using removable terminal boards located on the rear panel of the controller.

Connection of the controller clamps in the version with thermocouple



Connection of the controller clamps in the version with resistance input

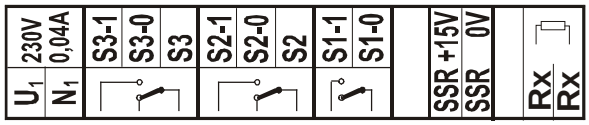
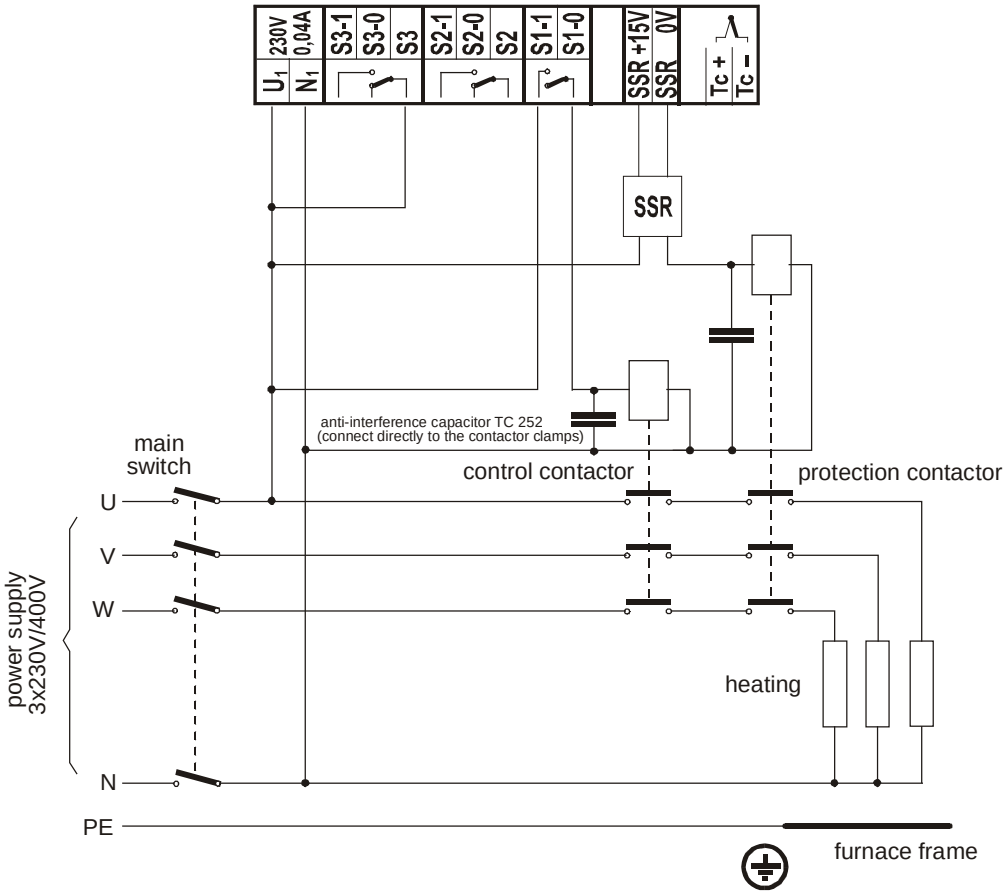


Fig. II.1 Connection of the controller clamps

It is forbidden to combine the supply to an input element (thermocouple, thermometer, etc.) with the power supply conductors to the controller and the control of the controlled system. The input element must be connected separately to prevent the measured variable from being influenced externally. If, for any reasons, this connection cannot be made separate, then it is necessary to make its shielding by insulated braiding which must be connected in one point with the grounding point as close to the controller as possible.

EXAMPLE OF CONNECTING THE CONTROLLER
(Switching of the heating by means of a contactor)

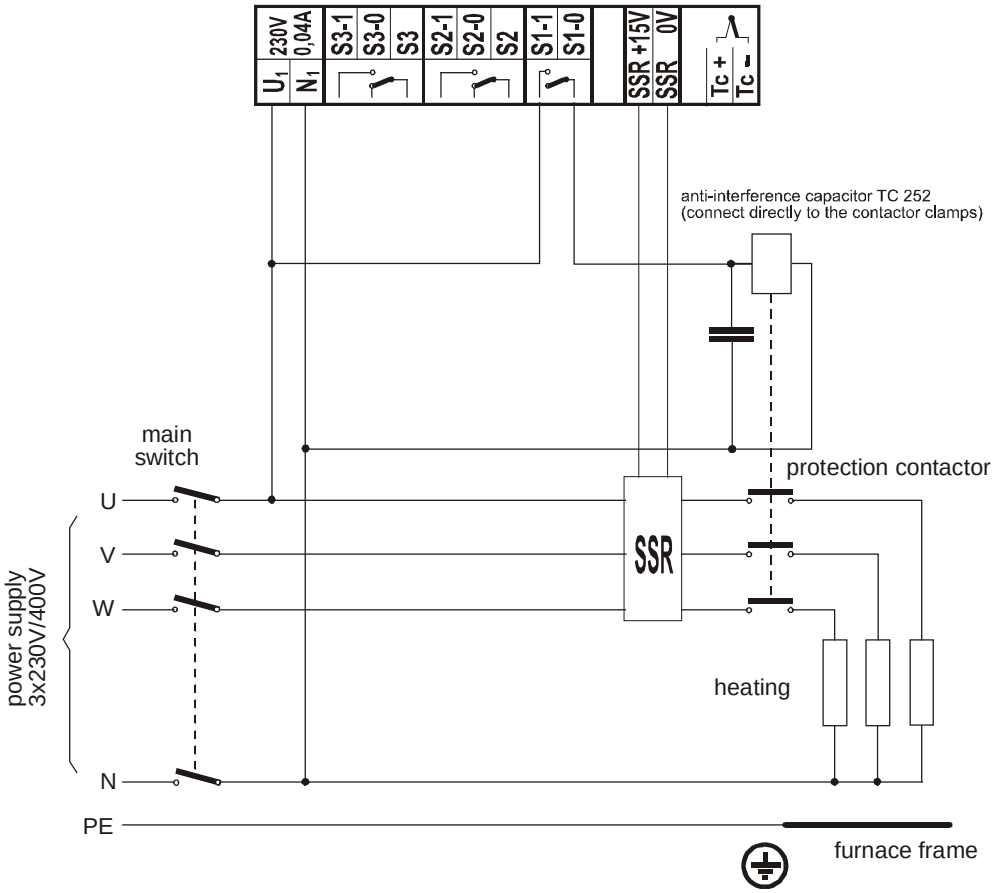


Possibility of using an additional protection contactor

If the heating is switched on by a contactor (the contacts of the S1 relay marked S 1-0 and S 1-1 serve this purpose), the R101 controller allows to use the output designed for the control of SSR for switching-on the protection contactor also in this mode. The protection contactor breaks the contacts in the case of the exceeding of the maximum temperature, failure of the thermocouple or a memory error simultaneously with the control contactor, its importance will, however, increase in the case of the "sticking together" (welding) of the contacts of the regulating contactor.

To control this protection contactor, a solid state relay is used (it is not included in the delivery), which is dimensioned for the current of the contactor control coil (SSR 400V/3A is sufficient) connected between the clamps of 0V and +15V.

EXAMPLE OF CONNECTING THE CONROLLER
(switching the heating by means of a SSR)



If you decide to use a solid state relay for switching the furnace heating, **a protection contactor must be inserted in the power supply line to the heating** (it is not included in the delivery) and must be dimensioned for the furnace heating input. The solid state relay has an advantage, in comparison to the contactor, in the fact that it cannot be worn down mechanically and a fine control can be achieved because it can switch on in incomparably shorter intervals than the contactor, but its great disadvantage is that, in the case of the dielectric breakdown of the semiconductor transition, it cannot be "closed" (disconnected). Such a breakdown of the SSR would cause uncontrolled operation of the furnace at full power and damage the charge or the entire furnace.

The protection contactor connects after switching on the controller and only disconnects if the maximum temperature, which the manufacturer of the furnace entered in the controller memory, is exceeded, or in the case of a fundamental failure, such as a defect of the temperature sensor or a memory error.

For switching the protection contactor, the contacts of the S1 relay are used, which is assigned, in the case that the controller is adjusted to the SSR operation, with the function of switching the protection contactor. The switching contacts for the control of the protection contactor are located on the rear side of the controller and are marked S1-0 and S1-1.

III. OPERATION OF CONTROLLER

Start of Controller, Condition of Controller after Power Supply Restoration

After connecting the power supply to the controller, its initialisation is executed, during which all display segments light. After the initialisation is finished, the controller displays the measured temperature.

In the event that the power supply has been interrupted during a control cycle, the controller continues the interrupted program from the point of the power failure. If the power failure happens during waiting for the start, the controller will start the program immediately.

Controller Run

After initialisation, the controller displays the measured temperature (or the corresponding data of the input sensor). This condition, when the controller performs measurement or measurement and control, is called a **measuring condition**; the condition, when the operator sets the controller by means of the keypad, is called an **operating condition**.

Control of Controller

The controller is controlled by means of a five-key keypad. The single keys of the keypad are assigned with the following functions:

In the measuring condition:

PROG	- Menu of operations with program – writing, adjustment, display
SET	- Menu of settings of the controller
TEST	- Display of a detected error and execution of the test of the controller
STOP	- Menu of changes of the program run and its end
START	- Start of program

In the operating condition:

⇧ - Increase in the value of a number / moving backwards in the menu
⇩ - Decrease in the value of a number / moving forwards in the menu
⇨ - Moving the cursor to the right
← - End without changes / leaving the menu
↵ - Confirmation of the set value and end/selection and confirmation of an item in the menu

Input of Program Number

The controller offers using as many as 16 programs. The individual programs are numbered from **0** to **9** and the other six positions as **A**, **B** to **F**. When operating a program, the controller first requires the number of the program with which the required operation is to be performed. The inquiry has the following form:

PRG x

After setting the required number, press the key **↵.**

The programs **A** to **F** can be "locked", i.e. their changes can be forbidden, which enables that the manufacturer of the furnace can set six programs designated to certain technological processes. Locking the programs is carried out in the service level.

IV. COURSE OF CYCLE

Before a program is entered, it is necessary to set a control mode according to the requirements for the course of temperature curve and the equipment of the furnace.

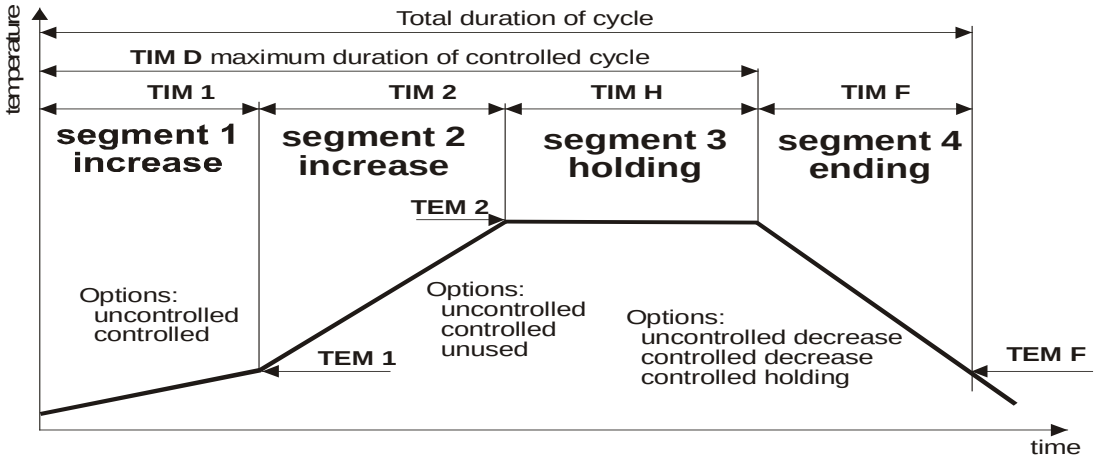


Fig. IV.1 Basic diagram of the controller program

The meaning of the individual abbreviations used in the diagram:

TEM 1, TEM 2, TEM F: target temperatures of the individual segments.
- **TEM F** is the final temperature at which the program will be ended.

TIM 1, TIM 2, TIM H, TIM F: duration of the individual segments.
- The controller, when a program starts, counts on the temperature of 25 °C. To keep the increase, it counts the duration **TIM 1** in the first segment according to the temperature measured at the start, so that the growth could be kept. Therefore, the duration **TIM 1** will change depending on the starting temperature.

TIM D: maximum duration of a controlled cycle.

Creating a program mode

For the individual segments, one of the offered options is selected.

SEG 1 Setting of Segment 1:
- uncontrolled — Only target temperature **TEM 1** will be set in the program
- controlled — Ttemperature **TEM 1** and duration of segment **TIM 1** will be set

SEG 2 Setting of Segment 2:
- uncontrolled — Only target temperature **TEM 2** will be set in the program
- controlled — Temperature **TEM 2** and duration of segment **TIM 2** will be set
- unused — The segment is not executed, nothing is set in the program; the controller will set temperature **TEM 2** equal to **TEM 1**

SEG 4 Setting of Segment 4:
- c. decrease — Temperature **TEM F** and duration of segment **TIM F** will be set
- unc. decrease — Target temperature **TEM F** will be set in the program
- c. holding time — Unlimited holding time at temperature **TEM 2**

TIM D Setting of time limit:
- used — The maximum duration of segments 1 to 3 – the maximum duration of controlled cycle **TIM D** will be set in the program
- unused — The time limit is not used

S2 Setting of the **S2** relay function

S3 Setting of the **S3** relay function

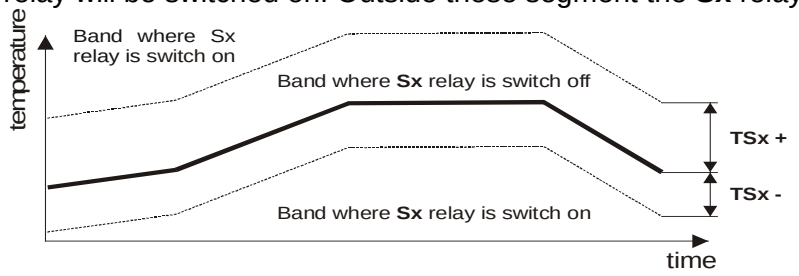
Options of setting S2 and S3 relays:

Both the **S2** and **S3** relay can be assigned with one of the following functions:

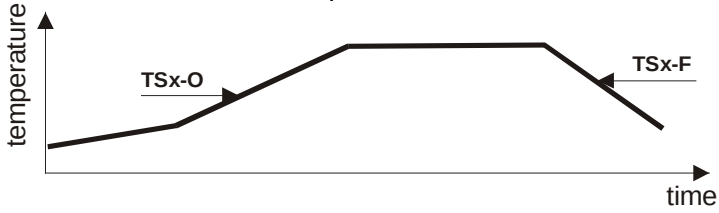
UNUSED **Sx** relay is not used in the program

SEGMENTS **Sx** relay is assigned with a state in each program segment
- In each segment of a program, it is set, whether the **Sx** relay is to be switched on/off for the entire duration of this segment
- It can be used, for example, for the change-over of the furnace "star/triangle"

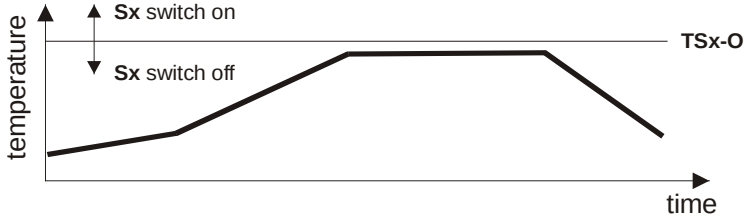
BAND Watching of the course of control
- Setting of a segment or segments and a band along these segments in which the **Sx** relay is switched off; if the temperature leaves the set interval, the **Sx** relay will be switched on. Outside these segment the **Sx** relay is switched off.



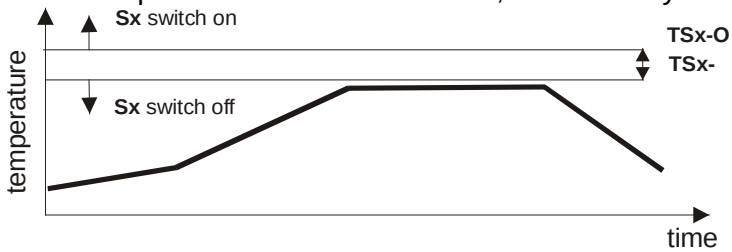
SERVO Control of the servo
- Setting of a segment in which the **Sx** relay is switched on if the temperature of switched on of the **TSx O** relay is reached and in which the **TSx F** relay will be switched off if the temperature of switched off is reached.



WATCHING Exceeding of the set watching temperature of a program
- Setting of temperature **TSx-O** at whose exceeding the **Sx** relay will be switched on; if the temperature in the furnace drops below temperature **TSx-S**, the **Sx** relay will be switched off.



HYSTE Exceeding of the set watching temperature of a program with hysteresis
- Setting of temperature **TSx-O** at whose exceeding the **Sx** relay will be switched on and hysteresis band **TSx. I**f the temperature in the furnace drops below temperature **TSx-S** minus **TSx-**, the **Sx** relay will be switched off.



V. PROGRAMMING OF CONTROLLER AND PROGRAM OPERATIONS

By pressing the **PROG** key in the measuring condition select the menu of the program operations If the use of password is active, the controller will display a call for its input: **H0000**. After the correct password has been entered and confirmed by the key ↵, the menu of program operations will open.

The controller will display an inquiry about the number of the program in which it offers the last used program number: **PRG x**. Confirm the set number by pressing the key ↵.

The controller will check the existence of the program with the set number. If such program does not exist, it will go to its construction – editing a program. If such program exists, the controller will display the menu of operations with this program:

OVER	Overwriting the selected program with a new one
EDIT	Changing the selected program (editing)
DISPL	Displaying the selected program

If the programs **A** to **F** are locked, they cannot be edited and can only be displayed. Locking the programs is carried out in the service level.

Editing a Program

A program is created according to the pre-selected mode – see Chapter IV Course of Cycle. In editing a program, the controller does not allow to enter a temperature higher than the set **maximum temperature**. If a higher temperature is entered, the controller will display the error message with the maximum temperature that may be set, e.g. **E1600**. Times are entered in the program in the form **HH-MM** (hours-minutes). Editing the program may be finished any time without a change by pressing the key ←. The following is a list of all values that can be entered in a program. The pre-selected mode designates which values will be actually entered in a program.

First segment – increase

The controller displays **TEM 1** and after any key is pressed, the target temperature of the first segment is displayed and then its change is expected. The set temperature is confirmed by the key ↵.

The controller displays **TIM 1** and after any key is pressed, the duration of controlled increase of the segment is displayed and then its change is expected ↵.

Second segment – increase

The controller displays **TEM 2** and after any key is pressed, the target temperature of the second segment is displayed and then its change is expected. The set temperature is confirmed by the key ↵.

The controller displays **TIM 2** and after any key is pressed, the duration of controlled increase of the segment is displayed and then its change is expected. The set value is confirmed by the key ↵.

Third segment – holding the target temperature

The temperature in the holding segment is **TEM 2**.

The controller displays **TIM H** and after any key is pressed, the duration of holding the target temperature is displayed and then its change is expected. The set value is confirmed by the key ↵.

Fourth segment – ending segment

The controller displays **TEM F** and after any key is pressed, the final temperature of the segment is displayed and then its change is expected. The set temperature is confirmed by the key ↵.

The controller displays **TIM F** and after any key is pressed, the duration of controlled ending of the program is displayed and then its change is expected. The set value is confirmed by the key ↵.

Maximum duration of controlled cycle

The controller displays a call to enter the maximum duration of the controlled cycle **TIM D**. After any key is pressed, the duration is set, and after it is exceeded the program starts Segment 4. The controller does not allowed to enter a time shorter than the sum of the times programmed.

Temperatures for the control of S2 and S3 relays

Watching the course of control (Band)

The controller displays a call to set a positive temperature deviation **TSx +** and after any key is pressed, the positive temperature deviation is displayed and then its change is expected. Then the setting of a negative temperature deviation **TSx -** follows and the setting is done in the same way.

Control of the servo

The controller displays the call **TSx O** to enter the temperature for switching on the **Sx** relay and after any key is pressed the temperature, at which the **Sx** relay is switched on, is set. Then the controller displays the call **TSx F** to enter the temperature for switch off the **Sx** relay and after any key is pressed the temperature, at which the **Sx** relay is switched off, is set.

Exceeding of the set watching temperature

The controller displays the call **TSx O** to enter the temperature of switching on the **Sx** relay and after any key is pressed, the temperature, at whose exceeding the **Sx** relay is switched on, is set.

End of editing the program

After the last program value has been entered, the controller will display the query for saving the program: **SAVE?** By pressing the key ↵ the program will be saved, by pressing any other key the program will not be saved and the controller will return to the measuring condition.

After the program has been saved, the controller will display the message **PRGOK** confirming that the program has been successfully saved. After any key is pressed, the editing of the program is finished and the controller will return to the measuring condition.

VI. PROGRAM RUN

Program Start

To start a program pressing the **START** key in the measuring condition. The controller will display an inquiry about the number of the program that is to be activated: **PRG x**. After the number is entered and confirmed by the key ↵, the controller will display the menu for start of the program:

NOW	Execute the immediate start of the program
WAIT	Execute the delayed start of the program
END	Do not start the program, return to the measuring condition

Delayed start of the program

The program will be activated after the set time has passed. The controller will display the call **TIM S** to enter the time of start. After it is confirmed, set the time of start **HH-MM** (hours-minutes). The controller will switch to the waiting condition, in which it displays the temperature and waits for the set time. During this, it displays the measured temperature for four seconds and regularly, for one second and in lower brightness, it displays the time that remains to the start of the program. At the same time, the first LED flashes on the curve of the course. After the waiting time has passed, the program will start.

Important caution!

If a power failure occurs during waiting for the start of the program, the controller will switch over, after the power supply is restored, to the START mode! (The program will start immediately.)

Start of the program

Before starting the program, the controller will check the setting and in the case of an error, the start will not be executed. If no error is found, the controller will display **START** and the program will be activated.

Variables Displayed during Program Run

If the program is running, the controller displays the temperature measured by the input sensor and, on the ramp of the course of program, a LED flashes on the position of the program segment that is currently in progress. According to the step of the program, it further displays, for one second and in lower brightness, the following:

First, second, and fourth segments: target temperature of the segment
Third segment: elapsed time of the segment

Interruption of Program Run

The program may be interrupted any time by pressing the **STOP** key. After it has been pressed, the controller will display the menu of program interruption:

END	The end of the program will be executed
SKIP?	A skip to the following step of the program will be executed
REPEA	The currently performed segment of the program will start again (it is only applicable in the segments with a set time)

VII. SETTING OF CONTROLLER

The control of the controller is divided into four levels. The first – the lowest – level is the operator level, which only allows to start and end the programs. The second is the technological level, which allows to set all control parameters, mode, etc. The third is the service level. It is accessible from the technological level and allows to set the type of the input sensor, maximum temperature, and selection of the switching element of the heating. The forth – the highest – is the manufacturer level. It is accessible from the service level and serves for calibration of the input. To enter the individual levels, a password is required.

Technological Level

Activate the technological level by pressing the **SET** key in the measuring condition. If the use of password is activated, the controller will display a call to its input: **H0000**. After editing the correct password and confirming it by the key ↵, the menu of the technological level will open:

DEV-T	Permissible temperature deviation	1 to 99 °C
TIM-C	Time constant	1 to 99 sec
PRO-C	Proportional constant	1 to 99
DER-C	Derivative constant	1 to 99
INT-C	Integration constant	1 to 99
MODE	Setting of control mode	
MAX R	Maximum temperature of reduced output	0 °C to maximal temperature
FALL	Allowable delay of controlled value	
VERS	Software version and serial number of the controller	
SET	Setting – service level	
U-PAS	Use of password in the technological level and program operations	
MAN	Manual control of S2 and S3 relays	

The time, proportional, derivative and integration constants influence directly the controlled process – control constants. To reach the highest quality of the control, the parameters of the control system must be known, so that the correct values of the control constants could be determined. Because these parameters are mostly not known, they must be set by trial according to the below-stated specifications.

The controller allows to change all control parameters during operation, but the changes in setting are only applicable in the next pass through the control cycle. The interval between the passes through the control cycle is given by the time constant.

Permissible temperature deviation

The permissible temperature deviation determines the band along the required temperature, in which the controller holds the actual temperature. This band is called a proportional band. The wider the proportional band is, the wider the temperature variation is and vice versa. But at the same time, the narrower the proportional band is, the more accurate setting of the time, derivative, and integration constants the control requires to be able to hold the temperature within the proportional band. Therefore, if the controller is not able to hold the temperature in the set proportional band, the control constants must be changed.

Time constant

It determines the frequency with which the control and switching of the heating is executed. The time constant corresponds to the transport delay of the controlled system, which means the slower the system, the higher the time constant.

Proportional constant

It determines the influence of the proportional band on the control, which means that the lower this constant is, the shorter the intervention of the controller is. The recommended value is 99, when, at the set value near 1, the influence of the proportional band is at a minimum level. This means that the control is rather ID than PID. The ID control is not recommended for its lower stability.

Derivative constant

It determines the influence of the derivative component of the control – the influence of the change rate on the controlled variable. The higher the value of the derivative constant is, the more the change rate of the controlled variable will be considered. The controller will react more quickly on the rate of changes. At the set value near 1, the influence of the derivative component is at a minimum level, which means that the control is rather PI than PID.

Integration constant

It determines the influence of the integration component of the control – a long-term deviation from the target value. The integration component performs the long-term adjustment of the controlled system to the zero deviation. It is only applicable in the segment of holding. The higher the value of the integration constant is, the quicker the adjustment to the zero deviation will be, but the higher inclination of the system to vibration will be. At the set value 1, the influence of the integration component is at a minimum level, which means that the control is rather PD than PID.

Recommended procedure for setting the control constants

Set the permissible deviation to the required value; a value lower than 3 °C is not recommended for the first setting. Then set the time constant, which should be set to a value from ~1 to 3s for quick furnaces with excess power, and to a value from ~5 to 10s for large and slower furnaces. Set the derivative constant to half the range, i.e. 50, and set the integration constant to the lowest possible value 1.

After starting the program and its switching to the controlled section (mostly the holding time), follow the switching frequency of the heating and, by changing the time constant, try to get the controller to a state when the switching frequency is as low as possible. At the same time, follow the deviation between the required and actual temperature. According to this deviation, adjust the derivative constant: If the controller reacts slowly to a decrease in temperature, increase the derivative constant; if the controller reacts quickly and overheats, decrease the derivative constant. If the controller does not reach the required temperature for a long time, increase the integration constant.

Control mode

The control mode is described in detail in the chapter "Course of Cycle". The following are only the individual options for setting.

The main menu of setting the control mode contains the following items:

SEG1	Setting of Segment 1
SEG2	Setting of Segment 2
SEG4	Setting of Segment 4
TIM D	Setting of the use of time limit
S2	Setting of the **S2** relay function
S3	Setting of the **S3** relay function

Setting of Segment 1

UNCON Segment 1 is not controlled
- Only the target temperature **TEM 1** will be set in the program

CONTR Segment 1 is controlled
- The target temperature **TEM 1** and the duration of the segment **TIM 1** will be set

Setting of Segment 2

UNCON Segment 2 is not controlled
- Only the target temperature **TEM 2** will be set in the program

CONTR Segment 2 is controlled
- The target temperature **TEM 2** and the duration of the segment **TIM 2** will be set

UNUSE Segment 2 is not used in the program
- This segment is not executed, nothing is set in the program, the controller sets the temperature **TEM 2** equal to the temperature **TEM 1** for Segment 3.

Setting of Segment 4

UNCON Segment 4 is an uncontrolled decrease
- The target temperature **TEM F** will be set in the program

CONTR Segment 4 is a controlled decrease
- The target temperature **TEM F** and the duration of the segment **TIM F** will be set

HOLD Segment 4 is unlimited holding duration
- Unlimited holding duration on the temperature **TEM 2**

Setting of time limit

UNUSE The time limit of the program run is not used

USED The time limit of the program run is used
- The maximum duration of Segments 1 to 3 – the maximum duration of the controlled cycle **TIM D** will be set in the program

Setting of the functions of S2 and S3 relays

UNUSE The **Sx** relay is not used in the program

SEGMS The **Sx** relay is assigned with a state for each segment of the program
- For each segment of the program, it is set whether the **Sx** relay is to be swiched on or off for the entire duration of this segment
- It may be used, for example, for the change-over of the furnace "star/triangle"

BAND Watching the course of control
- A segment or segments and a band along these segments, in which the **Sx** relay is switched off, is set; if the temperature exceeds the set interval, the **Sx** relay will be switched on. Outside these segments the **Sx** relay is switched off.

SERVO Control of the servo
- A segment is set, in which the **Sx** relay will be switched on if the temperature of servo open **TSx O** is reached, and a segment is set, in which the relay will be switched off if the temperature of servo close **TSx F** is reached.

WATCH Exceeding the set watching temperature of the program
- The temperature **TSx-O** is set, in whose exceeding the **Sx** relay will be switched on; if the temperature in the furnace drops below the temperature **TSx-S**, the **Sx** relay will be switched off.

HYSTE Exceeding the set watching temperature of the program with hysteresis
- The temperature **TSx-O** is set, in whose exceeding the **Sx** relay will be switched on and hysteresis band **TSx-**. If the temperature in the furnace drops below the temperature **TSx-S**, the **Sx** relay will be switched off.

For the segments

The individual segments of the program are assigned with the state of the relay (switched **O**n/o**F**f). Setting of the segments: The controller displays the number of segment and the setting of relay. By pressing the keys ⇧⇩ select the required setting of relay, by pressing the key ⇨ switch to the next segment. After pressing the key ↵, the changes will be saved and the setting of segments will be finished.

For the control of the servo

S_I-I	The servo closes and open in Segments 1 to 3
S_I-F	The servo closes in Segments 1 to 3, opens in Segment 4
S_F-I	The servo opens in Segments 1 to 3, closes in Segment 4 – reverse mode
S_F-F	The servo closes and opens in Segment 4

The temperature of switching on the relay **TSx O** and the temperature of switching off the relay **TSx R** will be set in the program.

For watching the course of control

It must be set, for the individual segments of the program, whether the watching of the course of control will be (**Y**es) or will not be (**N**o) performed.

Watching the course of control: The controller displays the number of segment and the setting of watching. By pressing the keys ⇧⇩ select the required setting of watching, by pressing the key ⇨ switch to the next segment. After pressing the key ↵, the changes will be saved and the setting will be finished.

The temperature above the temperature curve **TSx +** and the temperature below the temperature curve **TSx -** will be set in the program.

For exceeding the set watching temperature of the program

The watching temperature **TSx-S** will be set in the program.

Maximum temperature of reduced power

It is a temperature, to which the controller executes the control by lower power. This setting improves the course of control to a lower temperature. Until the maximum temperature is reached, the controller decreases the heating power and thus the non-required overshoot of temperature is reduced at lower temperatures. If the maximum temperature of the reduced power is set to 0, then the decrease in power is not executed.

When the controller is started for the first time, set the maximum temperature of the reduced power to 0. Make the firing and check the temperature, in which the unwanted overshoot occurs. Then set this temperature as the maximum temperature of the reduced power and the controller will control without overshoots.

Allowable delay of controlled value

It defines the maximal value that the immediate controlled value can differ from the required value within its increase or decrease. If the difference between the real and required value exceeds the set value the protective conductor is disconnected.

Version

The number of software version of the controller is displayed. After the following pressing of any key, its serial number will be displayed. To make dealings quicker and easier, please provide these numbers to the manufacturer if you discuss any problems you have with the controller.

Setting

Enter the service level. In the service level, settings that essentially influence the behaviour of the controller are carried out. It is only designated for service interventions and it is protected by a service password from entering an unauthorized person.

Use of password

It allows the engineer to disable the protection of access by password to the operations of modifying the programs and to enter the technological level.

NONE	Technological password is not used
SET	Technological password is used for the setting of control parameters
PROG	Technological password is used for modifying programs
ALL	Technological password is used for both programs and control parameters

Manual control of S2 and S3 relays

The controller provides the possibility to test the functionality of the relays. The controller displays the selected control element and its state. By pressing the key ⇨ switch among the control elements, by pressing the key ⇧ or ⇩ change the state of the element.

R2-x	R2 relay; 0 – the relay is switched off, 1 – the relay is switched on
R3-x	R3 relay; 0 – the relay is switched off, 1 – the relay is switched on

Service Level

Enter the service level from the technological level via the item setting and after the correct service password has been entered. In this level, the manufacturer of the furnace sets the type of the input sensor, maximum temperature of the furnace and selection of the output control element (heating).

TYP S	Type of input sensor
MAX T	Maximum permitted temperature of the furnace
CONTR	Selection of output control element
SHIFT	Shift of temperature (-25 to 50 °C)
LOCK	Lock/unlock programs **A** to **F** for making adjustments
COMPE	Setting of compensation of the line of the sensor (in resistance input only)
CALIB	Calibration – the manufacturer's level, where the input calibration is carried out
SER N	Setting of the serial number of the controller – can only be made by the manufacturer

Type of input sensor

The selection of the type of input sensor. Each sensor is assigned with the maximum and minimum permitted value of measured temperature (variable), in which the sensor can be used.

Voltage input sensor - thermocouple:

The name of thermocouple contains its maximum operating temperature.

J 700	J thermocouple in the range from 0 to 900 °C
K1000	K thermocouple in the range from 0 to 1300 °C
N1000	N thermocouple in the range from 0 to 1300 °C
S1300	S thermocouple in the range from 0 to 1600 °C
C2300	C thermocouple in the range from 0 to 2300 °C
U0-25	Voltage input from 0.00 to 25.00 mV in the range from 0 to 25.00 mV
U0-50	Voltage input from 0.00 to 50.00 mV in the range from 0 to 50.00 mV

Resistance input sensor in the range from 0 to 300Ω

Temperatures are read on the thermometer in accordance with the DIN 43760 standard.

PT100	Resistance thermometer in the range from –200 to 500 °C
R 100	Resistance input from 0 to 300 Ω

Resistance input sensor in the range from 0 to 3 000Ω

Temperatures are read on the thermometer in accordance with the DIN 43760 standard.

P 500	Resistance thermometer Pt 500 in the range from –200 to 500 °C
P1000	Resistance thermometer Pt 1000 in the range from –200 to 500 °C
N 500	Resistance thermometer Ni 500 in the range from –50 to 200 °C (Tk = 6180 ppm/°C)
N 505	Resistance thermometer Ni 500 in the range from –50 to 200 °C (Tk = 5000 ppm/°C)
N1000	Resistance thermometer Ni 1000 in the range –50 to 200 °C (Tk = 6180 ppm/°C)
N1005	Resistance thermometer Ni 1000 in the range –50 to 200 °C (Tk = 5000 ppm/°C)
R 500	Resistance input from 0 to 1500 Ω
R1000	Resistance input from 0 to 3000 Ω

Resistance input sensor in the range from 0 to 30 000Ω

Temperatures are read on the thermometer in accordance with the DIN 43760 standard.

P 5k	Resistance thermometer Pt 5000 in the range from –200 to 500°C
P 10k	Resistance thermometer Pt10000 in the range from –200 to 500°C
N 5k	Resistance thermometer Ni 5000 in the range from –50 to 200°C (Tk = 6180 ppm/°C)
N 5k5	Resistance thermometer Ni 5000 in the range from –50 to 200°C (Tk = 5000 ppm/°C)
N 10k	Resistance thermometer Ni10000 in the range from –50 to 200°C (Tk = 6180 ppm/°C)
N10k5	Resistance thermometer Ni10000 in the range from –50 to 200°C (Tk = 5000 ppm/°C)
R 5k	Resistance input from 0 to 15000 Ω
R 10k	Resistance input from 0 to 30000 Ω

Maximum temperature

It is the maximum constructional temperature at which the manufacturer of the furnace allows to operate the furnace. Its exceeding is signalled by the controller by displaying the upper horizontal line before the temperature and, at the same time, the controller switches off all heating systems and the protection contactor. The maximum temperature must be in the range specified in the table of the type of input sensor.

Important caution!

The controller cannot be operated above the maximum temperature, therefore, a higher temperature than the maximum temperature cannot be set in any segment of the program.

Control element

The furnace may be controlled by means of the contacts of the S1 relay (control of the power contactor) or by voltage for control of the power solid state relay (further SSR).

SSR	The controller controls the SSR, the S1 relay is used for the control of the protection contactor
RELAY	The controller controls the S1 relay, the input for SSR is used for the control of the protection contactor

Note: If the S1 relay is used for switching on the heating, it is necessary to take into consideration its mechanical and electrical service life, which is give by the number of its switching. Therefore, it is not suitable to use the relay for quick and frequent switching. (The switching frequency is given by the set time constant of the controller and by the dynamic behaviour of the controlled furnace. If the control parameters are set correctly, the switching frequency of the relay is low even at a low time constant).

Shift of temperature

For a possible increase in the accuracy of measurement, the controller allows to compensate the error of the temperature sensor (a thermocouple, a resistance thermometer). Temperature sensors are made with an error of ± some per cents and such an error can represent even a few degrees depending on the accuracy class and the type of sensor. Make the compensation of difference in temperature in the following way:

By using a precise (calibrated) thermometer, measure the temperature in the point where the temperature sensor is located. Then set the difference between the measured temperature

and the temperature displayed on the controller with the relevant sign as the shift of temperature. The manufacturer sets the shift of temperature to 0 °C

Locking of programs

The programs **A** to **F** may be "locked", i.e. their changes may be forbidden, which enables that the manufacturer can edit six programs designed for particular technological processes.

LOCK	Programs **A** to **F** are locked – they cannot be adjusted
UNLOC	Programs **A** to **F** are unlocked – they can be adjusted in any way

Line compensation – for resistance input only

In the version with resistance input, a two-wire connection for measurements is used. In order to ensure a precise measurement, the controller uses the software compensation of the line resistance. The compensation is carried out by reading the resistance of the line. The resistance amount may be measured either by the controller or it may be set from the keypad. To set the resistance amount, one of the following options can be selected:

MEASU	Make the resistance measuring of the line by using the controller
SET	Set the resistance amount of the line from the keypad

Line resistance measuring by using the controller

The controller displays **SHORT**. The operator of the controller will short-circuit the clamps of the resistance sensor as close to the sensor as possible. After short-circuiting the clamps, press the key ↵. The controller will measure the line resistance and display **SAVE?** By pressing the key ↵ the new resistance value will be stored in the memory. After the date has been stored, **OK** is displayed confirming that the operation has been executed successfully.

Setting the line resistance amount from the keypad

The controller displays the set amount of the line resistance. By using the keypad, set the amount of the line resistance. Confirm the set value by pressing the key ↵, the controller will display **SAVE?** By pressing the key ↵ the new resistance value will be stored in the memory. After the date has been stored, **OK** is displayed confirming that the operation has been executed successfully.

Input Calibration of Controller

The input calibration of the controller is made by the manufacturer or by an authorized service company. The accuracy of calibration has an essential influence on the accuracy of measurements performed by the controller.

Calibration of the controller in the version with thermocouple

The controller must be calibrated for the input range from 0 to 50 mV (**J 700**, **K1000**, **U0-50**) and for the input range from 0 to 25 mV (**S1300**, **U0-25**).

Make the calibration in the following way:

1. Connect a voltage supply with a precise voltmeter (with a minimum measuring accuracy of 0.01 mV) to the input clamps.
2. Enter the calibration by editing the correct password.
3. The controller will display a call for the setting of the voltage low limit (~0 mV) **L-LIM**. After setting the voltage low limit, press any key and set the voltage value in millivolts on the display, then confirm the set value by pressing the key ↵.
4. The controller will display a call for the setting the voltage high limit (~50 mV for input 50 mV and ~25 mV for input 25mV) **H-LIM**. After setting the voltage high limit, press any key and set the voltage value in millivolts on the display, then confirm the set value by pressing the key ↵.
5. The controller will display an inquiry whether the setting is to be saved **SAVE?**. After pressing the key ↵, the controller will save the new setting and will display **OK**. After pressing any key the new setting will not be saved and the old setting will remain effective.

Calibration of the controller in the version with resistance input

The controller must be calibrated for the input range from 0.0 to 300.0 Ω.

Make the calibration in the following way:

1. Connect a precise resistor (preferably a resistance decade) with a minimum accuracy of 0.1 Ω to the input clamps.
2. Enter the calibration by editing the correct password.
3. The controller will display a call for the short-circuiting of the input clamps (setting of resistance 0 Ω). After short-circuiting the input, press the key ↵. The controller will execute measurement and count the shift of input.
4. The controller will display a call for the setting the high range limit (~300 Ω) **H-LIM**. After setting the resistance of the high limit, press any key and set the resistance value in Ohms on the display. Confirm the set value by pressing the key ↵
5. The controller will display an inquiry whether the setting is to be saved **SAVE?**.
6. After pressing the key ↵, the controller will save the new setting and will display **OK**. After pressing any key, the new setting will not be saved and the old setting will remain effective.

Calibration for the ranges from 0 to 3,000 and from 0 to 30,000 is carried out in a similar way. Additionally, it is, however, necessary to carry out calibration for the half-ranges from 0 to 1,500 and from 0 to 15,000.

VIII. DETECTED ERROR CONDITIONS

The controller carries out permanent checks whether the measure value has not exceed the permitted maximum limit (maximum temperature), whether the input sensor has not been short-circuited, and whether the input sensor poles are not reversed. Furthermore, the controller checks, while reading the setting, the individual settings, and checks the program while reading it

Indication of Detected Errors

If the controller detects an error, dots start flashing on the display until the error is eliminated and the operator presses the **SEL** key. Setting errors may only occur if there is a failure of the controller memory; the controller will not make possible that a faulty value be set.

By pressing the **SEL** key, the operator will find out the detected error that he will have to eliminate, or he must inform an authorized person or a service department on the error. The following detected errors may occur:

TEM ¯	Input sensor disconnected
TEM _	Temperature measuring is outside the range
TEM M	Maximum temperature of the furnace has been exceeded
E-T-D	Error of temperature deviation setting
E-T-C	Error of time constant setting
E-P-C	Error of proportional constant setting
E-D-C	Error of derivative constant setting
E-I-C	Error of integration constant setting
E-MOD	Error of control mode setting
E-R-P	Error of reduced power setting
E-P-N	Error program number
E-PRG	Program error – the only error that ends the program run
E-SEN	Error of input sensor setting – Service engineer's intervention is necessary
E-M-T	Error of maximum temperature setting – Service engineer's intervention is necessary
E-CAL	Error of input calibration setting – Service engineer's intervention is necessary
E-SHI	Error of temperature shift setting – Service engineer's intervention is necessary
E-T-R	Error of the relative temperature sensor – only in the voltage input for thermocouple with the compensation of temperature of the cold end of thermocouple – Service engineer's intervention is necessary
E-COM	Error of line compensation setting – in the version with resistance input only – Service engineer's intervention is necessary
NONE	The plant is faultless

Errors of input sensor

The error of the disconnected input sensor and the error of the exceeding of maximum temperature cause that the controller will switch off the protection contactor (if used), and if the program is running, it will switch off the output element (the heating). After the errors have been eliminated, the controller will return the protection contactor (if used) to the connected condition, and if the program is running, the controller will allow it to switch on the output element.

The controller indicates the error from its occurrence to its elimination and testing (the **SEL** key) by flashing dots on the display.

If there is an error, the controller displays it at the same time in the following way:

- The error of exceeding the maximum temperature: an upper horizontal line appears in the left upper corner of the display and dots flash.
- The error of disconnected input sensor: upper horizontal lines appear on the entire display

The error of temperature measuring outside the range (the cold end of thermocouple line is hotter than the hot one) is only indicated by lighting lower horizontal lines on the entire display – it has no influence on the operation of the controller. If this error occurs, dots do not flash on the display.

Behaviour of the controller in the case of an error of relative temperature

It is only applicable for the controller with a memory input for a thermocouple with compensation of the temperature of its cold end:

In the event that an error of the relative temperature sensor occurs, the controller's display will start flashing with dots, and a vertical line will appear on the display in the segment closest to the graphical display of the course of cycle. At the same time, the controller will start to use the relative temperature of 25 °C for counting the temperature. If this error occurs during the program run, the controller will finish this program by using the relative temperature of 25 °C. During the error of the relative temperature sensor, the controller does not allow to start any other program until this error is eliminated.

Behaviour of the program if an error is detected

If the controller detects an error, the controller will not allow to start a new program. If a program is running, it can only be ended by an error while reading the program.

Behaviour of the program in the case of a power failure

The controller will execute initialisation and, if no error is detected, it checks whether a program is running. If a running program is detected, the program continues from the point where it was interrupted. If a program is in the condition of waiting for the start, such program will be started immediately.

IX. R101 CONTROLLER SETTING SUMMARY

Key	Menu				setting	M. set
SET	**DEV-T**	Permissible temperature deviation			1-99	5
	TIM-C	Time constant			1-99	5
	PRO-C	Proportional constant			1-99	99
	DER-C	Derivative constant			1-99	50
	INT-C	Integration constant			1-99	5
	MODE	**SEG1**	**UNCON**	Segment is not controlled		CONTR
			CONTR	Segment is controlled		
		SEG2	**UNCON**	Segment is not controlled		CONTR
			CONTR	Segment is controlled		
			UNUSE	Segment is not used		
		SEG4	**UNCON**	Segment is uncontrolled		UNCON
			CONTR	Segment is controlled		
			HOLD	Unlimited holding time at TEM 2		
		TIM D	**UNUSE**	The time limit is not used		UNUSE
			USED	The time limit is not used		
		S2	**UNUSE**	The S2 relay is not used		UNUSE
			SEGMS	The S2 is assigned with a state for each segment of the program		
			BAND	Relay with band function		
			SERVO	Relay with servo function		
			WATCH	Monitoring relay		
			HYSTE	As WATCH with hysteresis		
		S3	as S2			UNUSE
	MAX R	It is a temperature, to which the controller executes the control by lower power				0.0
	FALL	Allowable delay of controlled value				0.0
	VERS	Software version and serial number of the controller				
	SET	**TYP S**	Type of input sensor			
		MAX T	Max. permitted temperature of the furnace			
			RELAY	The controller controls the S1 relay		RELAY
			SSR	The controller controls the SSR,		
		SHIFT	Shift of temperature			0
		LOCK	**LOCK**	Lock/unlock programs A to F for making adjustments		UNLOCK
			UNLOCK			
		COMPE	**MEASU**	Line compensation – for resistance input only		SET
			SET			
		CALIB	Calibration and setting of the serial number of the controller - the manufacturer level password required			
		SER N				
	U-PAS	**NONE**	Technological password is not used			NONE
		SET	Password is used for the setting of control parameters			
		PROG	Password is used for programs modification			
		ALL	Password is used for programs and contr. parameters			
	MAN	**R2-x**	Manual control of S2 and S3 relays			
		R3-x	0 – the relay is switched off, 1 – the relay is switched on			
PROG	Menu of operations with program – writing, adjustment, display					
TEST	Controller's self-test execution and error display if any					
STOP	Menu of changes of the program run and its termination					
START	Start of the program					

X. GUARANTEE CONDITIONS

The manufacturer guarantees the faultless function of the controller for the period of 24 months from the date of putting the controller into operation, however, not longer than for 27 months from the date of sale to the customer. During this period, the manufacturer will make free of charge any repairs of faults caused by a material defect or by a hidden production fault.

The guarantee does not include faults caused by mechanical damage of the controller, incorrect connection, or its use for a purpose different from that for which it has been designed, by breach of operating or storage conditions, and by non-observance of the manufacturer's instructions. The service place is the manufacturer's plant.

Caution:

In the event of an error of the input circuit of the input sensor (a short-circuit on the line of the sensor, a fault of the input amplifier or converter), the controller may indicate the incorrect value of the measured variable. The manufacturer of the controller does not guarantee any secondary damage caused by the fault of the controller.
The manufacturer recommends that the controlled system is protected by another separate circuit that will disconnect the controlled system if the maximum permitted value of the measured variable is exceeded.

XI. WORKING CONDITIONS

The controller may operate in the environment protected against the direct influence of weather, radiation heat, dirt, and aggressive vapours, such as those in laboratories. The controller has been calibrated by the manufacturer for the selected input sensor.

Voltage:	230V/3VA, 50 to 60Hz
Operating temperature:	0 °C to 40 °C
Storage temperature:	-40 °C to 65 °C
Relative air humidity:	max. 80 % at 20 °C
Dustiness:	max. 0.5 mg/m^3 of incombustible and non-conducting dust

Production number:

Manufacturer's address, orders, technical information:
SMART, spol. s r.o.
Purkyňova 45
612 00 BRNO
Czech Republic

Tel: 00420-541 590 639
Fax: 00420-549 246 744
00420-541 241 706
E-mail: smart@smartbrno.cz
www.smartbrno.cz