UDK 536.581

Umerjanje in preverjanje delovanja termostatov

Calibration and Performance Control of Thermostats

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V prispevku opisujemo umerjanje in preverjanje delovanja termostatov. Obravnavamo vzdrževanje temperature, ko je ta približno enaka temperaturi okolice ter uporabo mehke logike pri regulaciji hitrih temperaturnih sprememb.

The temperature regulation of a liquid medium near the ambient temperature and the use of a fuzzy logic algorithm to control temperature sweeps of the same medium are analyzed.

1 OPIS PROBLEMA

V določenih fazah proizvodnje termostatov je treba umeriti ali preveriti karakteristike izdelkov. Temelj tovrstnim meritvam so razmeroma natančna temperaturna merjenja. Izvedbe običajno ne pomenijo posebnih tehničnih problemov, zahtevnejše so le regulacije temperature medijev v bližini temperature okolice in hitre temperaturne spremembe. V prispevku se bomo omejili na umerjanje in preverjanje termostatov, ki so namenjeni za temperaturno območje delovanja med 273 K in 373 K. Podobne so rešitve tudi za širše območje, le ustrezen medij moramo uporabiti.

2 TEHNIČNA REŠITEV

V vrsti toplotnih kadi, ki sestavljajo ustrezno proizvodno linijo, uporabljamo temperature, ki so blizu sobni temperaturi, pa tudi take, ki so mnogo višje od nje ter blizu ledišča vode.

Temperaturo medija v kadi, ki se znatno razlikuje od temperature okolice, k tej se nagiba temperaturni proces, potem ko preneha zunanje dovajanje oziroma odvajanje energije, vzdržujemo razmeroma preprosto s standardnimi industrijskimi izvedbami regulatorjev in ustrezni izvedbi toplotnih kadi. V našem primeru, gre za vzdrževanje temperature določene količine vode, se izkažeta električni grelnik in hladilna cev kot ugodna rešitev.

Energijo, ki jo dovajamo v sistem z električnim grelnikom, uravnavamo z določitvijo periode ter razmerja ko greje in ko ne greje. Podobno krmilimo tudi elektromagnetni ventil, ko medij hladimo.

1 DESCRIBING THE PROBLEM

At a certain stage in the thermostat manufacturing process the characteristics of the products need to be measured or monitored. The basis for this procedure is a relatively precise measurement of temperature. The implementation of this procedure does not present any technical problem. Possible exceptions are temperature regulation of the medium when it is close to the ambient temperature and rapid temperature sweeps. This article focuses on calibrating and monitoring responses of thermostats intended for use between 273 K and 373 K. By using appropriate medium, similar solutions can be applied to a broader temperature range.

2 TECHNICAL SOLUTION

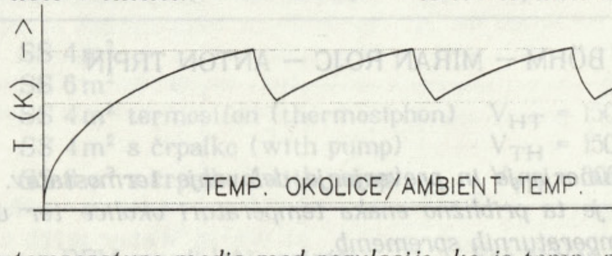
In a series of several thermal baths, which form the production line, room temperature is used, as well as temperatures which are much higher or are close to the water freezing point.

The temperature of a medium in a bath, which is considerably different from the ambient temperature, towards which the thermal process tends after the external energy supply has been switched off, can be easily maintained with implementation of standard industrial regulators and the use of appropriate thermal baths. In our case of maintaining the temperature of a certain volume of water, an electric heater and a water cooling coil prove to be a useful solution.

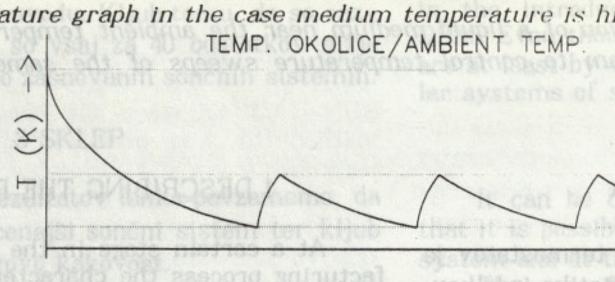
The power which is delivered to the system by the electric heater is maintained by determining the period and proportion of heating and not heating. When the medium is cooled, the electric valve is controlled in the cooling circuit in the same way. The efficiency of the regulating process

Uspešnost regulacije procesa je v končni fazi odvisna od vrste regulatorja ter nastavitve parametrov regulacije. Na sliki 1a je prikazan temperaturni potek, ko je zahtevana temperatura medija v kadi višja od temperature okolice, medtem ko je na sliki 1b prikazan primer, ko je temperatura v toplotni kadi nižja od tiste v okolici.

is ultimately determined by the type of regulator used and the setting of its parameters. Figure 1a shows the temperature flow when the required temperature of the medium should be higher than the ambient temperature. Figure 1b shows the reverse case when the temperature of the medium is lower than that of the environment.



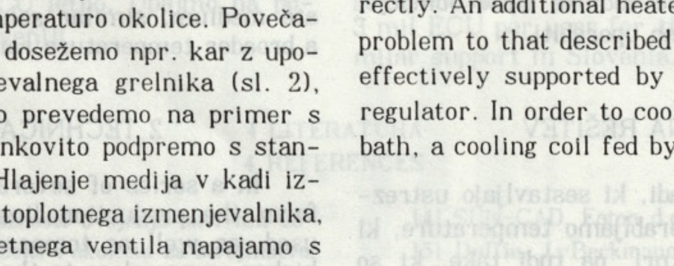
Sl. 1a. *Potek temperature media med regulacijo, ko je temp. medija višja od temp. okolice*
Fig. 1a. *Temperature graph in the case medium temperature is higher than ambient temperature*



Sl. 1b. *Potek temperature medija med regulacijo, ko je temp. medija nižja od temp. okolice*
Fig. 1b. *Temperature graph in the case medium temperature is lower than ambient temperature*

Za vzdrževanje temperature v bližini sobne temperature pa nobeden od omenjenih primerov ni neposredno uporaben, ker se temperatura okolice običajno spreminja nepredvideno, lahko je nekaj časa nad želeno temperaturo, nekaj časa pa pod njo. V tem primeru si lahko pomagamo tako, da navidezno povečamo temperaturo okolice. Povečanje temperature okolice dosežemo npr. kar z uporabo primernega dogrejevalnega grelnika (sl. 2), tako da rešitev dejansko prevedemo na primer s slike 1b, ki ga lahko učinkovito podpremo s standardnim regulatorjem. Hlajenje medija v kadi izvedemo preko kačastega toplotnega izmenjevalnika, ki ga prek elektromagnetnega ventila napajamo s primerno ohlajeno vodo.

To maintain the temperature in the vicinity of room temperature, since the ambient temperature changes constantly and can be either above or below the desired temperature for some time, none of the mentioned cases can be applied directly. An additional heater (Fig. 2) will bring the problem to that described in figure 1b and can be effectively supported by a standard temperature regulator. In order to cool the liquid medium in a bath, a cooling coil fed by cold water is used.



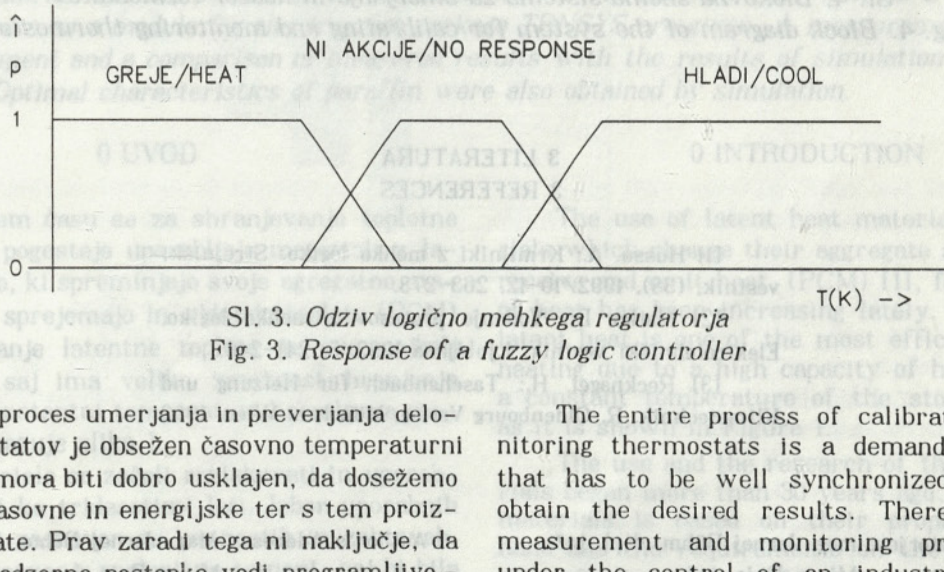
Sl. 2. *Izvedba toplotnih kadi za primer temp. medija približno enaka temp. okolice*
Fig. 2. *Bath realization for the case medium temperature approx. equal to ambient temperature*

Delovanje termostata je treba preveriti tudi v nekaj temperaturnih točkah z zvezno temperaturno spremembo. Tu se mora temperatura medija spreminjati s predpisano hitrostjo oziroma strmino. Večji energijski vložek, ki ga potrebujemo pri izpeljavi temperaturne spremembe, dovedemo prek dodatnega električnega grelnika, medtem ko pospešeno hlajenje dosežemo z uvajanjem hladne vode (prelita voda prosto odteče).

Regulatorji z uveljavljenimi algoritmi (npr. PID) se ob podobnih temperaturnih skokih ne obnesejo najbolje. Tedaj si lahko pomagamo z logično mehko regulacijo. Primer odziva regulacije z mehko logiko vidimo na sliki 3. Seveda pa standardni PID regulator spet prevzame regulacijo v končni fazi, ko je umiritev sistema skoraj že zadovoljiva. V našem primeru se je izkazalo, da določitev kriterijev le ni tako dolgotrajen postopek, kakor to včasih navaja literatura. Naloga je bila morda lažja tudi zato, ker smo jo lahko skrčili na raven proporcionalnega krmilnika.

The performance of the thermostat also needs to be checked at a few individual temperature points during fast temperature swing. In this case the temperature of the medium must change at a prescribed rate. A great energy impact is required in order to achieve this, which can be provided by employing an additional electric heater. Rapid cooling, on the other hand, can be achieved by introducing fresh water to the bath, allowing the excess water simply to spill over.

A temperature regulator with established algorithms (e.g. PID) does not always handle temperature jumps well. Instead, a fuzzy logic controller can be used. An example of fuzzy logic controller response is shown in Figure 3. A classical PID controller again takes control when the system settles to a satisfactory extent. In our case, we were able to establish the linguistic criteria considerably faster than sometimes mentioned in literature. Our task was perhaps easier as we reduced it to the problem of the proportional controller.



Sl. 3. *Odziv logično mehkega regulatorja*
Fig. 3. *Response of a fuzzy logic controller*

Celoten proces umerjanja in preverjanja delovanja termostatov je obsežen časovno temperaturni postopek, ki mora biti dobro usklajen, da dosežemo zadovoljive časovne in energijske ter s tem proizvodne rezultate. Prav zaradi tega ni naključje, da merilne in nadzorne postopke vodi programljivo - industrijsko krmilje, ki podpira tudi uporabniški vmesnik za vnos podatkov. Krmilje tako skrbi za ustrezno komunikacijo s temperaturnim regulatorjem, opravlja krmiljenje električnih grelnikov, mešalnih motorjev in hladilnih ventilov. Hkrati krmili še semaforske luči prek katerih spremljamo stanje v toplotnih kadeh ter otipava stanja stikal in tipk, s katerimi preprosto aktiviramo predpisane temperaturne spremembe v toplotnih kadeh.

Tehnologija proizvodnje termostatov zahteva, da v času umerjanja termostatov upoštevamo temperaturno delovanje okolice na diastat termostata. Programska oprema krmilja odpravlja tudi omenjeni vpliv, ki ga upoštevamo še pri podajanju oziroma prikazovanju vrednosti na semaforjih ob kadeh, kar predvsem uporabniku poenostavi informacijo o temperaturi v toplotni kadi.

The entire process of calibrating and monitoring thermostats is a demanding procedure that has to be well synchronized in order to obtain the desired results. Therefore, all the measurement and monitoring procedures are under the control of an industrial controller that also supports a user data interface. The industrial controller also communicates with the temperature controller and runs the electric heaters, circulator motors and cooling vents. Simultaneously it displays information about the process, controls the display lights and monitors the keyboard by which predefined temperature changes in the thermo bath are activated in a simple way.

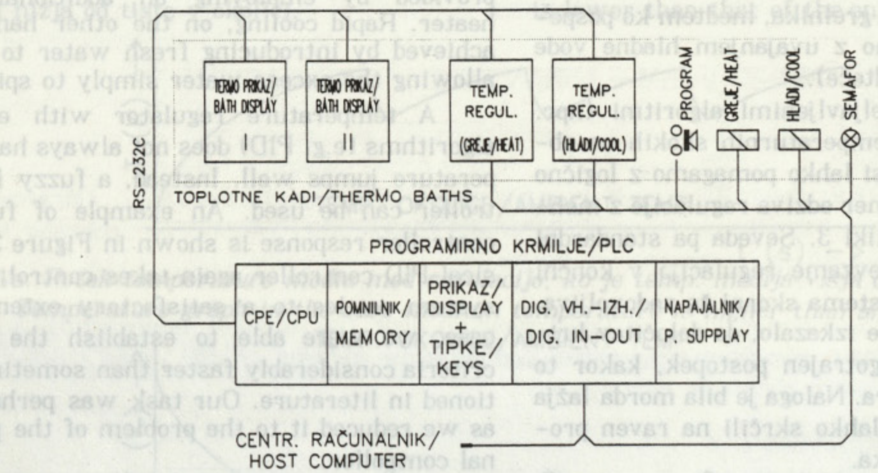
The technology of the production of thermostats also requires that the compensation of temperature parameters due to instantaneous ambient temperature is taken into consideration. PLC software controls them and also provides data correction for data displays, thus making their presentation to users simpler.

Brez posebnih težav lahko na omenjeni sistem vežemo tudi varovanje energijske konice v tovarni ter avtomatski izklop v času, ko proizvodnja ne teče.

Blokovna shema takega sistema je prikazana na sliki 4.

With no great difficulty can the described system be connected to the host factory load computer to protect peak energy consumption and switched off during non-production times.

Figure 4 shows the scheme of such a system.



Sl. 4. *Blokovna shema sistema za umerjanje in nadzor termostatov*

Fig. 4. *Block diagram of the system for calibrating and monitoring thermostats*

3 LITERATURA
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Prejeto: 23.3.1994
Received:

Sprejeto: 5.5.1994
Accepted: