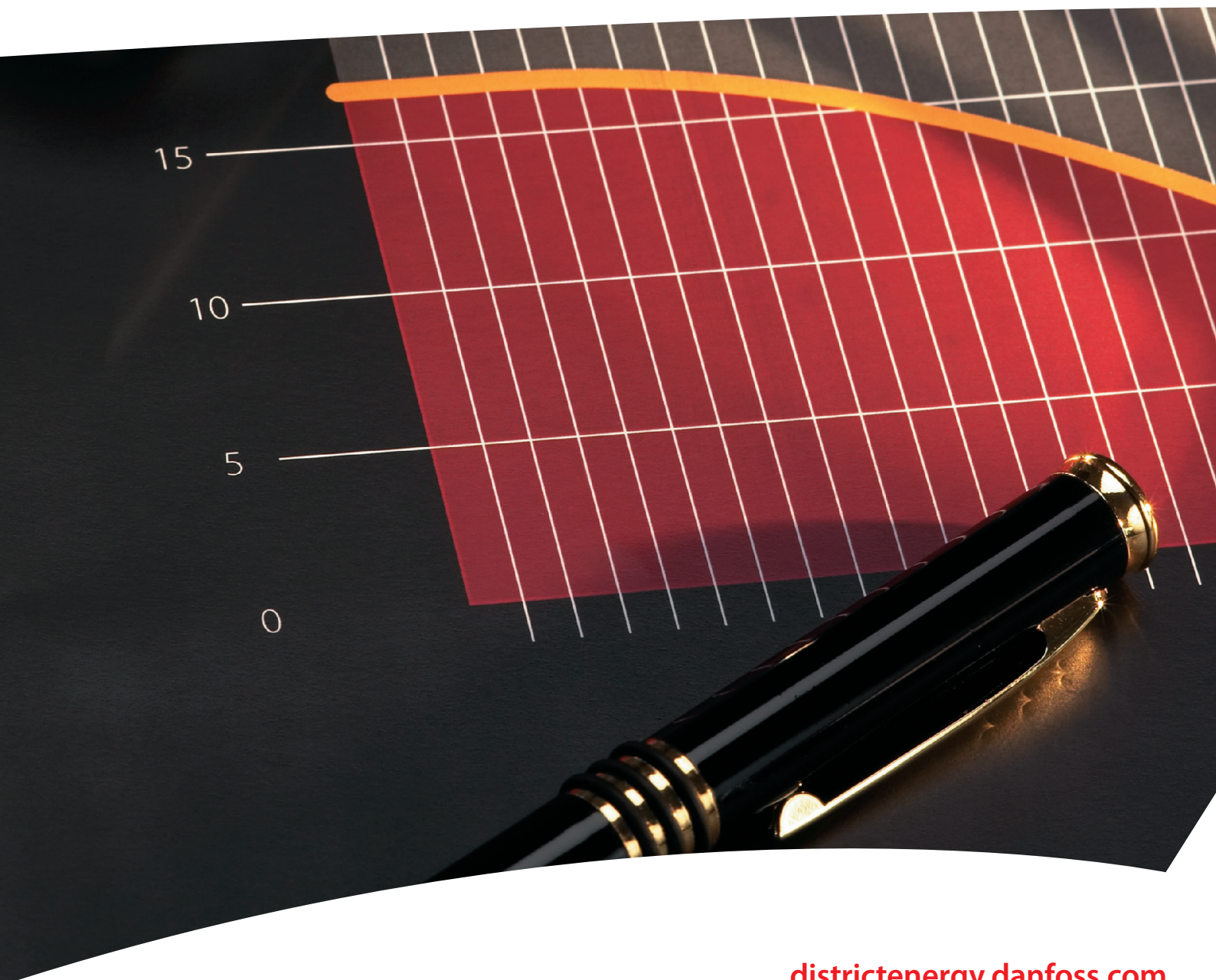


Technical paper

Auto tuning and motor protection as part of the pre-setting procedure in a heating system

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TECHNICAL PAPER

Auto tuning and motor protection as a part of the pre-setting procedure in a heating system

AUTOTUNING: Adaptive setting of a domestic hot water service controller.

MOTOR PROTECTION: Automatic setting of a controller during low performance.

A precondition for a well functioning heating system is that the correct settings are made before it is put to use. Adjustments are necessary to preset the regulating parameters. This article deals with the way in which the automatic setting of system control parameters is performed and the advantages this gives.

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Why pre-set a heating system?

Pre-setting gives the following benefits:

- A high degree of comfort
- Improved protection against lime deposits in domestic hot water heat exchangers
- Energy saving

- Long operating life
- Minimum service

Experience shows that the necessary settings are often not made or that they are inadequate. The reasons can be as follows:

- Ignorance of the importance of pre-setting

- Lack of instruction in setting
- No money has been allocated for pre-setting
- No agreement has been made on system pre-setting

The consequence is that the system will not function as intended.

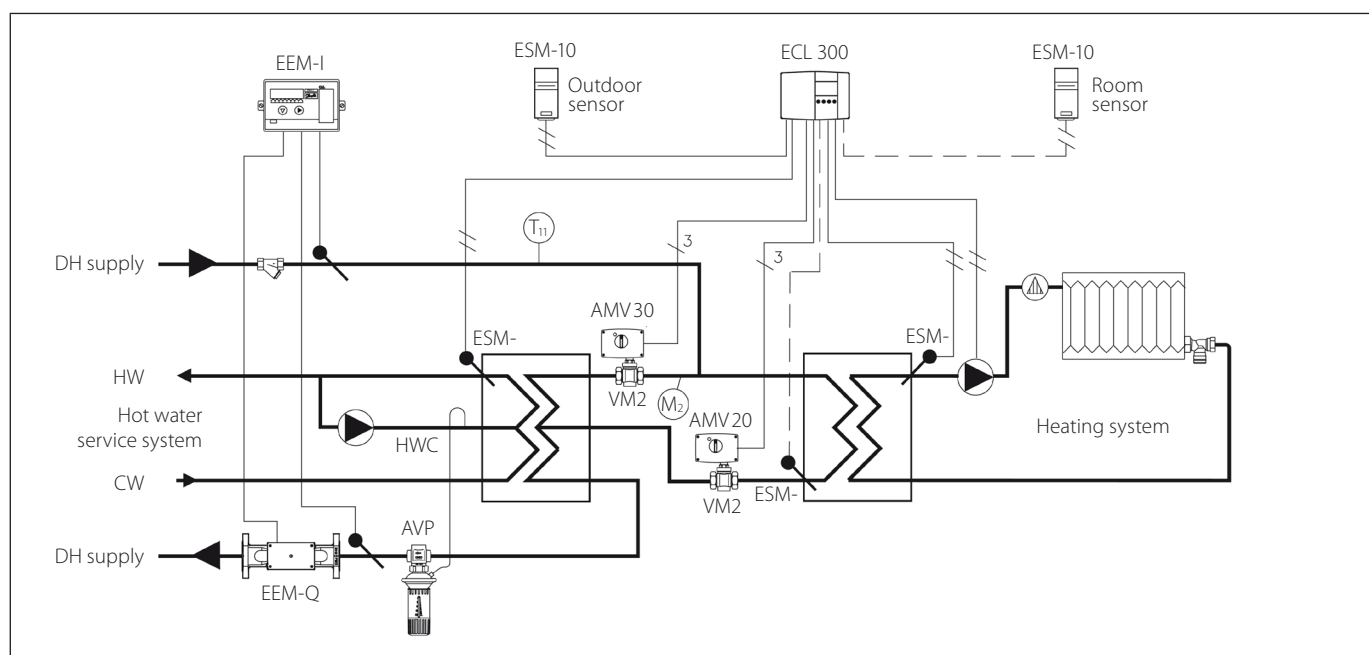


FIGURE 1: Typical consumer substation in a district heating installation with a heating system and domestic hot water system

Setting a consumer substation in a district heating installation

A district heating substation in a large supply installation usually consists of a room heating system and a domestic hot water system (fig.1). Such stations are often equipped with electronic regulators. Pre-setting includes setting the regulating parameters for both the heating and domestic hot water systems.

The heating system is of course not particularly dynamic, in that load changes are usually a result of changes in the outdoor temperature and periodic reductions in the heat output. This is a form of operation that does not impose very high demands on the regulator in order to maintain constant flow temperature in the heating system. Here, the regulator factory settings, based on calculations and experience, are often sufficient to make further adjustments unnecessary. Settings of this type are not dealt with in this article.

The opposite is true with the domestic hot water system. In this case the load changes concurrently with the consumption of hot water. Short but considerable load changes are frequent and the demand for high regulating accuracy and domestic hot water temperature stability is high.

For several reasons, flow systems such as the one shown in fig.1 have won approval in district heating systems that incorporate domestic hot water heating. Experience also shows that it is this type of system that imposes the greatest demands on regulating equipment and regulator setting parameters.

Setting a regulator for a heating system

District heating and domestic hot water systems of the type shown in fig.1 are normally equipped with PI regulators. To ensure a regulated temperature of satisfactory quality the various parameters of the regulator must be set.

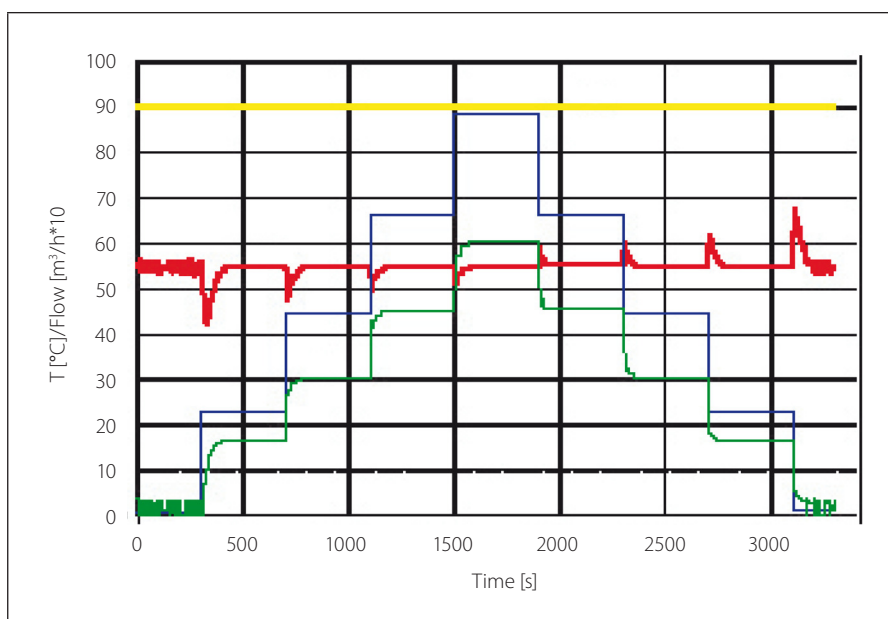


FIGURE 2: Simulation of typical test in accordance with the recommendations of the Finnish District Heating Society/1/

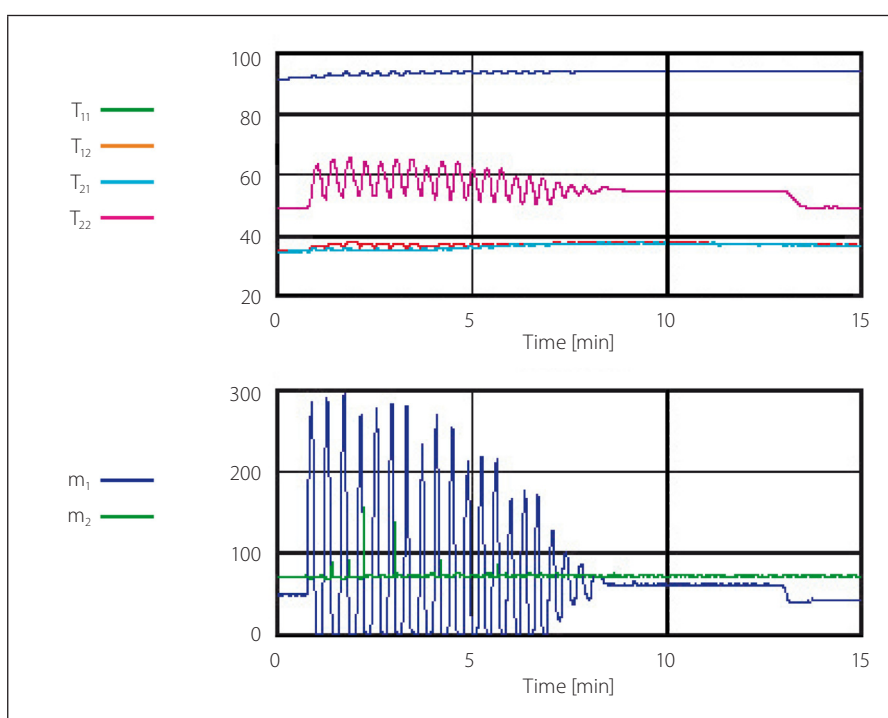


FIGURE 3: Balancing valves, flow limiters and flow controllers, which can be used in district cooling systems to maintain a hydraulic balance.

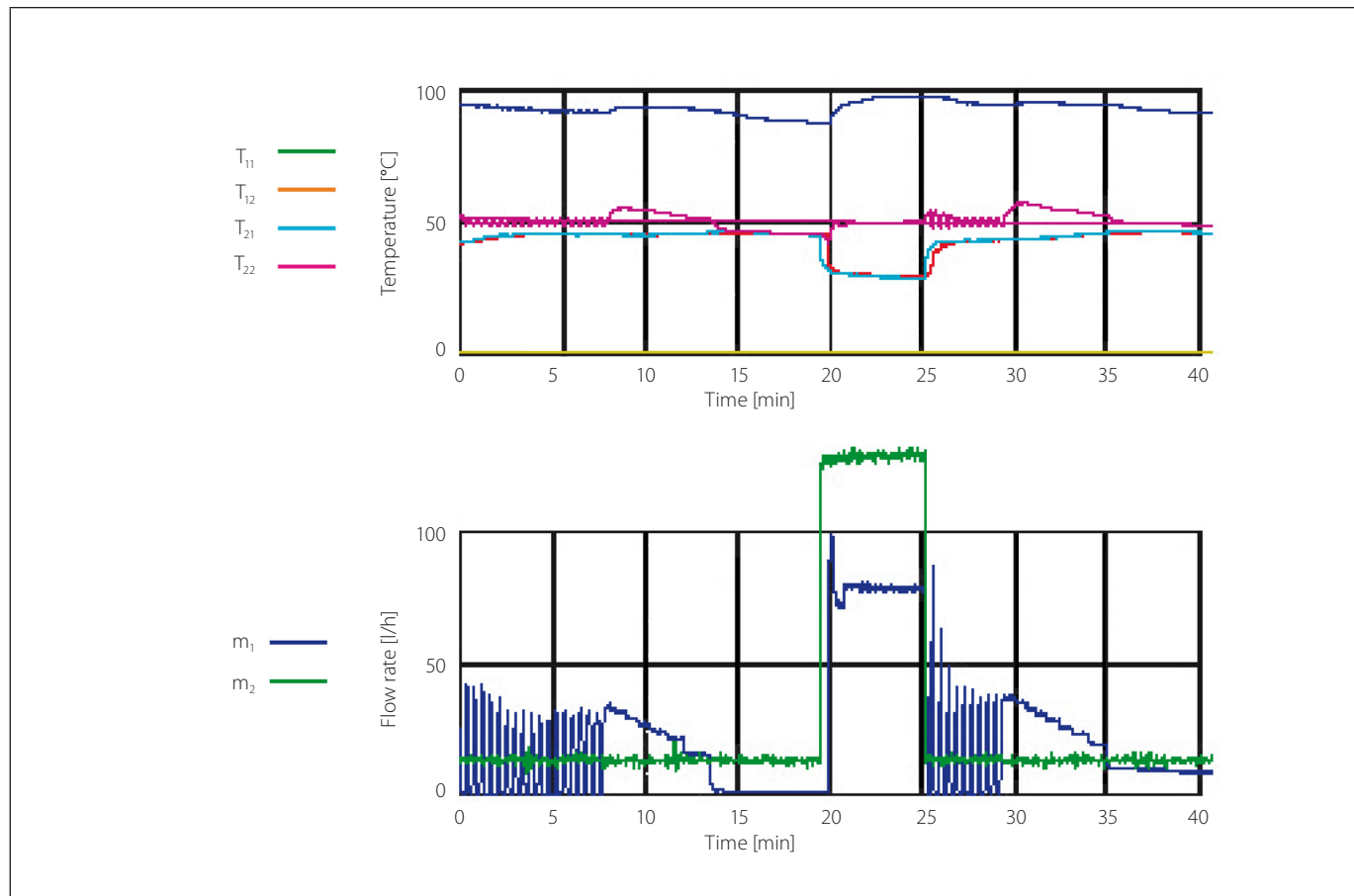


FIGURE 4: Differential pressure control and flow limitation of a heat exchanger system in a district-cooling network.

The settings involved are as follows:

- Neutral zone N_z
- Proportional band X_p
- Integration time T_n
- Motor constant T_v

The proportional band setting (X_p) affects the extent to which the regulator reacts to a temperature variation. A small X_p gives high amplification and fast reaction to a given temperature variation, but carries with it the risk of unstable temperature. A large X_p gives low amplification and only slight reaction to temperature variation, which means sluggish regulation with high temperature variations when the load changes.

The integration time (T_n) affects recovery of the set temperature. A short integration time gives fast recovery, but a risk of instability. A long integration time gives stable regulated temperature, but long recovery time.

Setting the valve motor constant (T_v) takes account of the motor running

time and the valve stroke. The output signal of the regulator is adjusted accordingly.

Setting these parameters requires good knowledge of the heating system parameters and of the regulator, which has to be set. If the technician concerned has little experience of making such settings, it can be a very time-consuming process. Among the parameters of significance to pre-setting are the following:

- System operating temperatures
- System load variations
- Valve motor speed
- Motorised valve characteristic
- Heating system time constant
- Differential pressure across the motorised valve

What are the demands on domestic hot water temperature regulation?

The demands most often made in connection with the regulation of

domestic hot water temperature involve:

1. Set temperature recovery
2. Temperature stability
3. Max. temperature variation on load change
4. Recovery time after a temperature variation on load change.

In its requirements and instructions for the installation of district heating consumer stations, the Finnish District Heating Society /1/ gives recommendations on the regulating accuracy of temperature in domestic hot water systems.

Table 1 shows the requirements contained in the recommendations on the regulating accuracy of temperature in domestic hot water systems issued by the Finnish District Heating Society /1/.

The requirements in table 1 relate to domestic hot water temperature accuracy in connection with load change and constant operation.

The requirements are as follows:

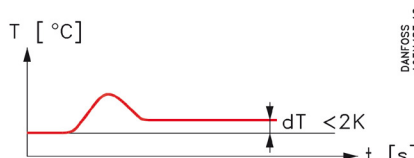
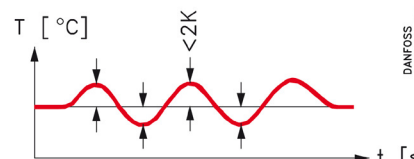
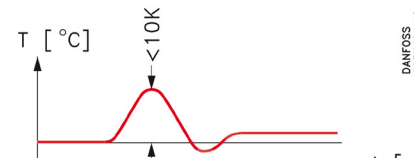
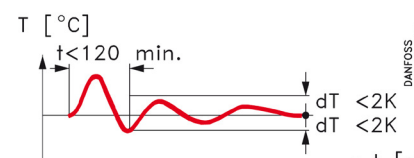
Requirement	Temperature variations	Settings	Effects
Max. constant permanent deviation from set point after a temperature change, ± 2 K	 DANFOSS A93N485.12	Nz Neutral zone	Small Nz setting improves recovery accuracy with risk of unstable flow temperature.
Max. permanent temperature hunting, ± 2 K	 DANFOSS A93N485.12	Xp Proportional band Tn Integration time	Small Xp gives fast-acting system with risk of hunting. Short Tn gives fast system with risk of hunting.
Max. temperature variation during operation, 10 K	 DANFOSS A93N484.12	Xp Proportional band	Small Xp gives small variations, but with risk of hunting.
Recovery time after a temperature change, ± 2 K within 120 seconds	 DANFOSS A93N486.12	Tn Integration time	Long Tn gives long recovery time of set temperature.

TABLE 1: Recommendations on the regulating accuracy of temperature in domestic hot water systems.

1. Max. constant temperature variation from set point after a temperature change, ± 2 K.
2. Max. permanent temperature hunting, ± 2 K.
3. Max. temperature deviation during operation, 10 K.
4. Recovery time after a temperature change, ± 2 K within 120 seconds.

Testing the domestic hot water system

To test these parameters it is necessary to run a tapping programme in which the system is loaded in steps of 25% up to 100% load and then down again to 0%. During 0% load the test is run with a consumption corresponding to the circulation of domestic hot water in the system.

A typical example of this procedure is shown in fig. 3. The problems in fulfilling the requirements of the recommendations can be seen in the changes of flow from 0%-25% and from 25%-0%.

The test parameters shown in the simulation, fig. 3, and the tests, fig. 4 and fig. 5 are:

- T_{11} District heating flow
- T_{12} District heating return
- T_{21} Domestic cold water temperature
- T_{22} Domestic hot water temperature
- m1 District heating flow
- m2 Domestic hot water flow circulation of domestic hot water in the system.

Temperature stability, recovery capability and settling time show no particular problems during testing under the given conditions.

However, it can be seen that the deviation in domestic hot water temperature exceeds the recommended max. 10 K from the setting. Furthermore, there are problems with temperature stability during no-load operation where the load corresponds to the heat loss in the circulation lines.

During no-load conditions, the motorised valve operates with a very small degree of opening and the valve

characteristic is very steep. The consequence is high amplification. /2/, /3/, /4/.

The hunting during no-load operation shown in fig. 2 is seen very often in domestic hot water systems. Hunting imposes high demands on the quality of the motor and regulator; the motor is cut in and out very frequently and is thus subjected to much wear.

If the regulator is equipped with output relays the frequent switching has a significant effect on the life of the regulator. If regulators with triac output are used, this form of operation does not load the regulator in the same way.

Auto tuning

From the above explanation of the effect of regulating parameters on temperature regulation it can be seen that there is a contradiction between the settings that improve stability and those that reduce deviations.

Smaller regulation deviations require a smaller Xp setting. This increases the

risk of hunting, and hunting during no-load operation becomes amplified. A larger X_p setting gives rise to greater deviations in the domestic hot water temperature during load changes. In contrast, the domestic hot water temperature during no-load operation becomes more stable.

The conclusion must be that there ought to be different regulator settings, depending on whether the system operates while hot water is being consumed or whether it is operating under no load.

Experience with the operation of domestic hot water systems, tests in laboratories and dynamic computer simulations have led to the development of an automatic setting function that is able to satisfy both conditions: a setting function (auto tuning) for automatically setting X_p and the motor constant in a consumption situation and a function (motor protection) that changes setting parameters during no-load operation. In this way stable operation is ensured. Patents have been applied for both functions.

The setting of the regulator for a domestic hot water system with auto tuning is now limited to just the following:

1. Loading the system with a constant tapping flow corresponding to the simultaneous opening of several taps.
2. Activation of auto tuning on the regulator.
3. Waiting 7-15 minutes until auto tuning has been completed.

Fig. 3 shows a test in which auto tuning has been initiated. The test shows where the regulation of domestic hot water goes from an unstable to a stable situation when the regulator setting parameters are being changed. In this light, the settings thus arrived at will be the optimum.

The setting of motor protection occurs automatically during system operation.

Figure 4 shows a test result from a no-load operation situation. Regulation becomes stable after a relatively short time, which is what happens when regulator settings are changed automatically.

In addition, after about 19 minutes of operation a further tapping period of approximately 6 minutes takes place and the regulator settings are changed automatically to the values set for auto tuning. After final tapping, the regulator again performs a parameter change so that once again the temperature becomes stable during no-load operation.

Conclusion

The introduction of automatic setting of regulation parameters on the regulator itself, i.e. auto tuning and motor protection, gives optimum regulation of the domestic hot water system. This ensures a high degree of comfort, stable regulation during no-load operation and, subsequently, longer motor life. The setting of regulator parameters can thus be reduced to one simple and reliable procedure. Auto tuning is especially necessary in domestic hot water systems.

Parameter setting for heating systems is not as critical, although in such systems motor protection in the regulator can be relevant.

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- [4] Boysen H.: *District heating house substation and selection of regulating valves*, Danish Board of District Heating News from DBDH Journal number 2/1999.

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- [1] *Valve characteristics for motorized valves in district heating substations*, by Atli Benonysson and Herman Boysen
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