Dynamic Properties of Recirculation

Jensen, Lars

1974

THE LUND INSTITUTE OF TECHNOLOGY

DEPARTMENT OF
BUILDING SIENCE

DIVISION OF
AUTOMATIC CONTROL

REPORT 1974:5

Dynamic properities of recirculation

L H Jensen

DYNAMIC PROPERITIES OF RECIRCULATION

L.H. Jensen

This work has been supported by Grant D698 from the Swedish Council for Building Research to the Department of Building Science and the Division of Automatic Control, Lund Institute of Technology, Lund, Sweden.

Abstract

Dynamic systems with recirculation can be described with different differential equations. These equations are in most cases impossible to solve. An approximation is made for a given system. A comparison is also made with real data from an airconditioning plant. The main behaviour is well described by the approximation.

Table of contents

1 Introduction

In many climate system some kind of recirculation takes part of air or water. The degree of recirculation in comparison with the total constant flow is usually controlled. A simple approximation shows that the temperature of the flow in the recirculation loop can approximately described with a first order system with a time constant. This time constant depends of the degree recirculation and the static gain of the dynamics included in the recirculation loop.

The approximation is made in section 2. In section 3 a comparison is made between a computed and a measured timeconstant from experiments with an air conditioning plant with a recirculation loop.

2 Approximation

A plant with recirculation can be described as a closed loop consisting of a pure transportation delay and a dynamic part as in figure 2.1 below

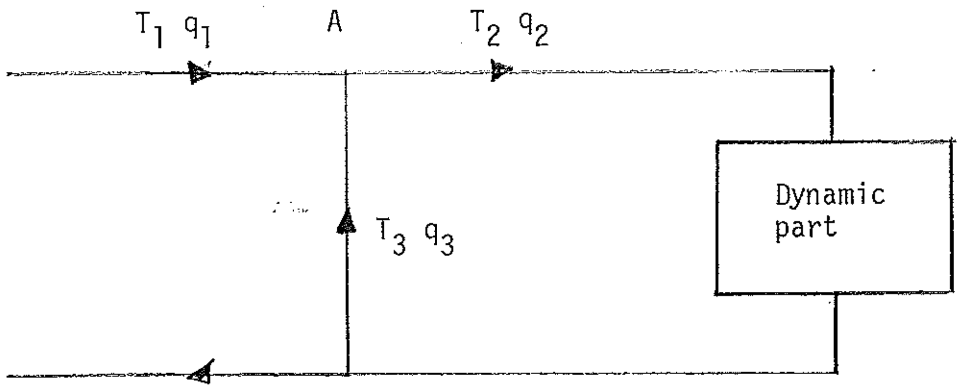

Figure 2.1 Recirculation loop

A heat balance equation and a mass balance equation can be set up for the mixing point A.

$$T_1(t) \cdot q_1 + T_3(t) \cdot q_3 = T_2(t) \cdot q_2 \tag{2.1}$$

$$q_1 + q_3 = q_2 \tag{2.2}$$

It is no limitation to set $q_2 = 1$ flow unit. This flow q_2 is almost constant. The flow q_1 is usually controlled by a valve. The temperature $T_1(t)$ is usually constant.

The inlet or outlet temperature $T_2(t)$ or $T_3(t)$ can be found as a solution to a difference differential equation. Equations of this type are difficult to solve.

If all dynamics is neglected except its static gain k then the outlet-temperature $T_3(t)$ will be piecewise constant if a step is made in $q_1T_1(t)$. The length of the piecewise constant $T_3(t)$ is the recirculation time. The recirculation time is chosen as time unit and one gets:

$$T_3(t) = KT_2(t-1) \tag{2.3}$$

With the equations (2.1), (2.2) and (2.3) one gets a first order difference equation:

$$T_2(t) - K(1-q_1)\, T_2(t-1) = q_1\, T_1(t) \tag{2.4}$$

If the main time constant of the dynamic part is about the same as the recirculation time then the outlettemperature will be a rather smooth curve if a step made in q_1. The steps would vanish. The difference equation (2.4) can be assumed as a sampled first order differential equation. This equation has a very smooth solution in continuous time. This curve might be a good approximation of the real outlettemperature.

The output is the outlettemperature $T_3(t)$ and the input is the product $q_1T_1(t)$. The dynamic properities of this system can be approximately described by a first order system with the gain K and the time constant $T = -1/\ln\,(K\cdot q_3)$.

In most plants $K\cdot q_3$ is less than one. Otherwise the system will be instable. The time constant T is given for different values of the product $K\cdot q_3$ in table 2.1 and in figure 2.2.

One conclusion is that a high static gain K will make the time constant T very load dependant. The recirculation q_3 is usually something between 50 to 100% of the total flow q_2.

Table 2.1

The timeconstant T in recirculation time units as a function of $K \cdot q_3$ ($T = -1./\ln (K \cdot q_3)$)

	0.02	0.04	0.06	0.08	0.10
0.0-	0.26	0.31	0.36	0.40	0.43
0.1-	0.47	0.51	0.55	0.58	0.62
0.2-	0.66	0.70	0.74	0.79	0.83
0.3-	0.88	0.93	0.98	1.03	1.09
0.4-	1.15	1.22	1.29	1.36	1.44
0.5-	1.53	1.62	1.72	1.84	1.96
0.6-	2.09	2.24	2.41	2.59	2.80
0.7-	3.04	3.32	3.64	4.02	4.48
0.8-	5.04	5.74	6.63	7.82	9.49
0.9-	11.99	16.16	24.50	49.50	-

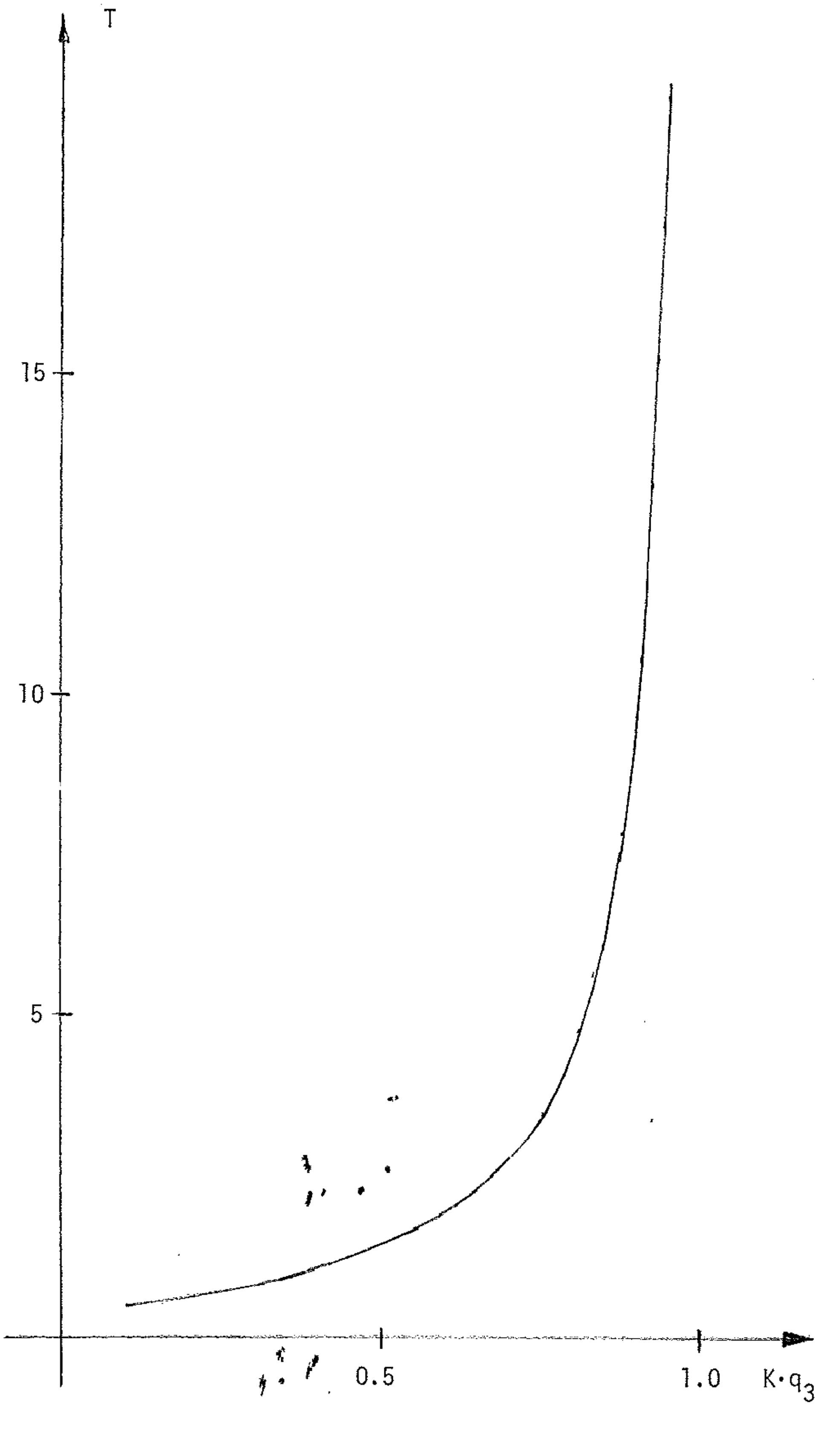

Figure 2.2 The timeconstant T in recirculation time units as a function of $K \cdot q_3$ ($T = -1./\ln(Kq_3)$)

3 Comparison with experiment data

Some experiments with an airconditioning plant have been made as a master thesis work (Jensen 1970). The plant containes a recirculation of water through a water to air crossflow heat-exchanger. The experimental data three stepresponses 1, 2 and 3 are shown in figures 3.1 - 3.3. The step was introduced in the mixing valve so that the recirculation changed as a step. The recirculation was 100% before the step. The sampling interval was 4 seconds. The static gain K was computed to 0.8 in steady state. The degrees of recirculation in the different stepresponses was computed to 0.91, 0.77 and 0.50. The recirculation time was determined to 40 seconds by measuring the constant flow and the volume of the recirculation loop. The computed time constants for the stepresponses are given in table 3.1. The timeconstants can also be crudely estimated with the slope of the outlettemperature in the figures 3.1-3.3.

Table 3.1

Time constant in seconds for a recirculation loop.

Experiment	Computed	Estimated
1	125	136
2	83	100
3	45	68

The figures in table 3.1 show that the simple model of the recirculation loop is useful to describe the dynamics. The simple model gives an idea how the plant will behave even when the included dynamic in the recirculation loop cannot be neglected.

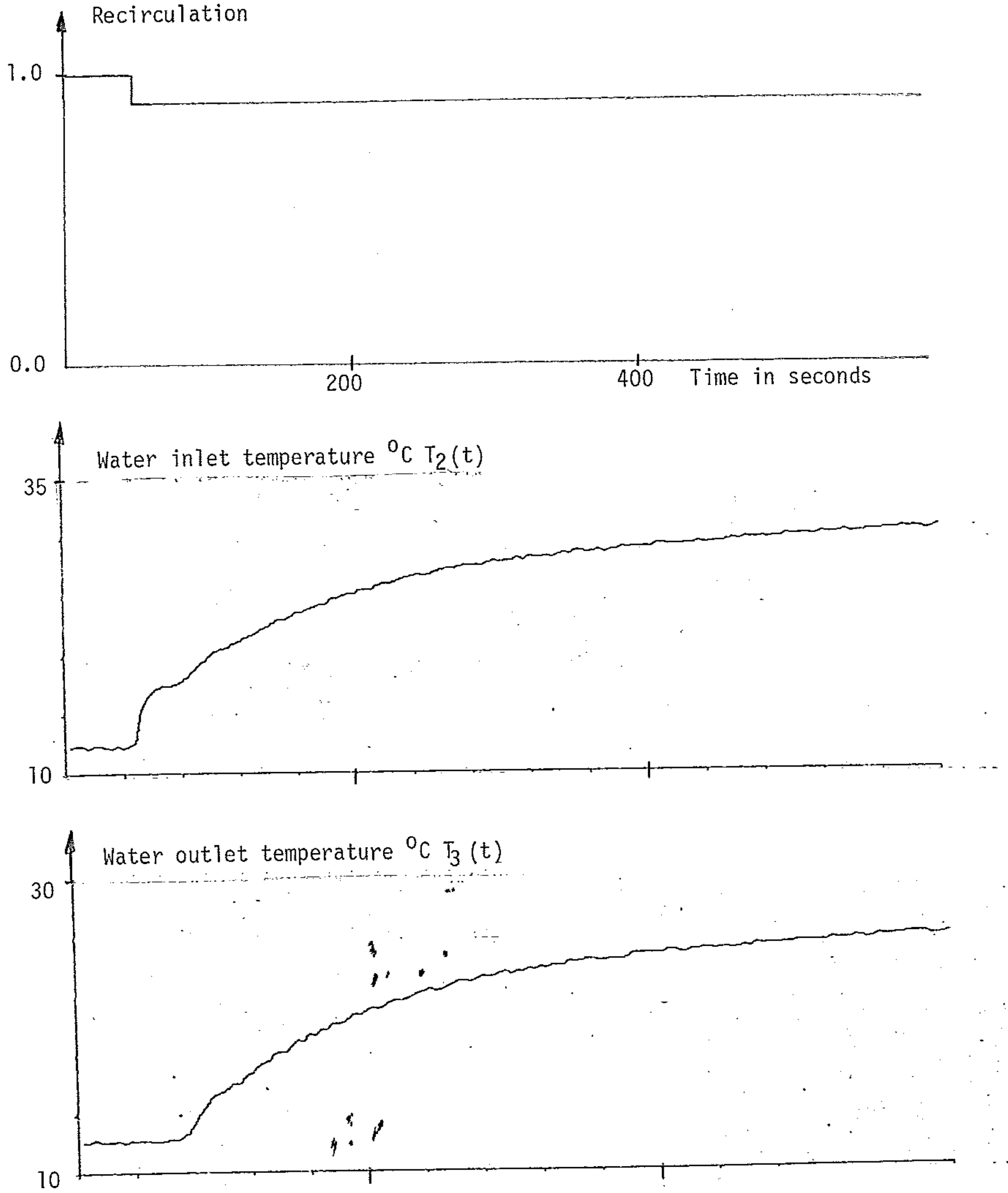

Figure 3.1 Experiment 1

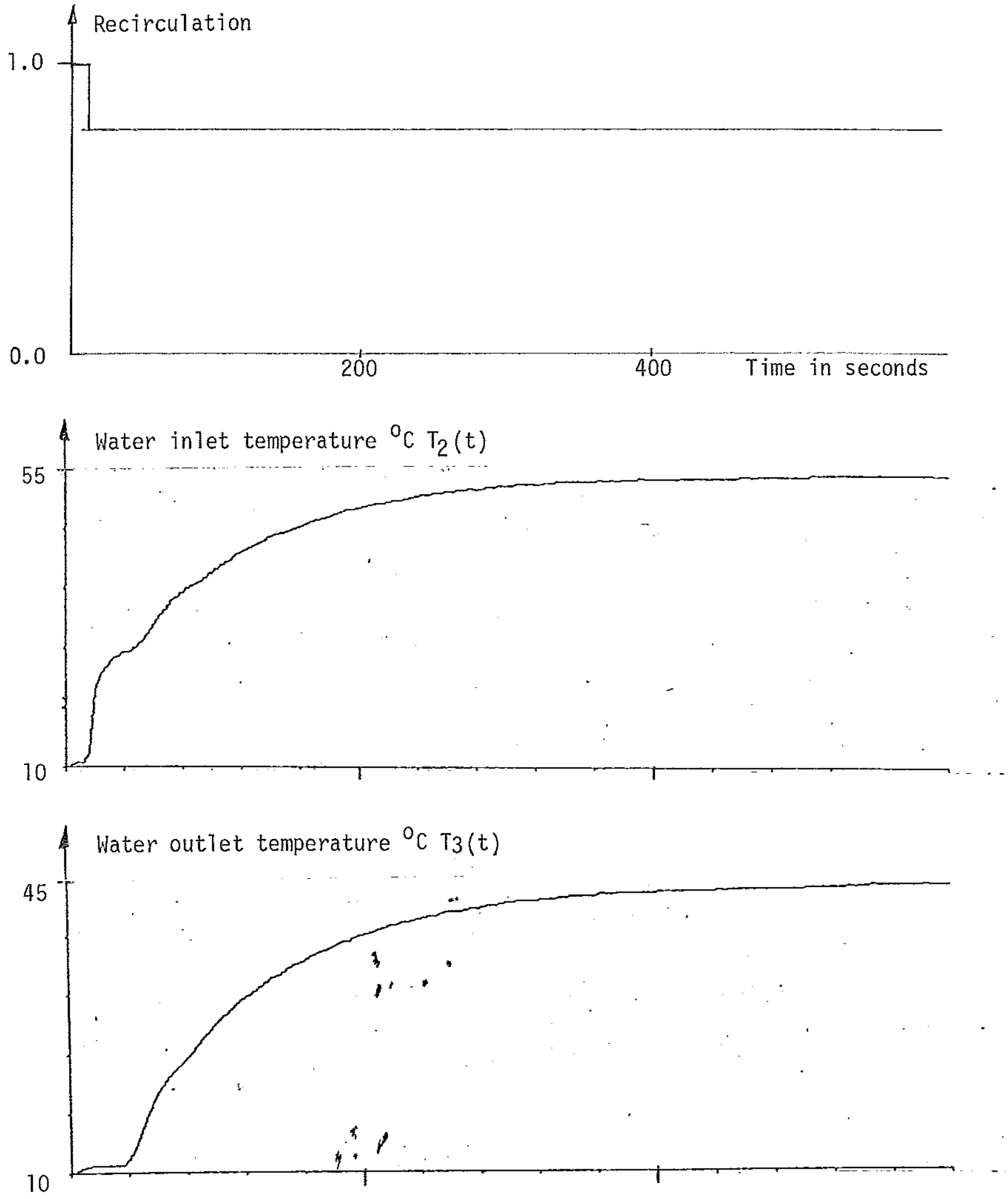

Figure 3.2 Experiment 2

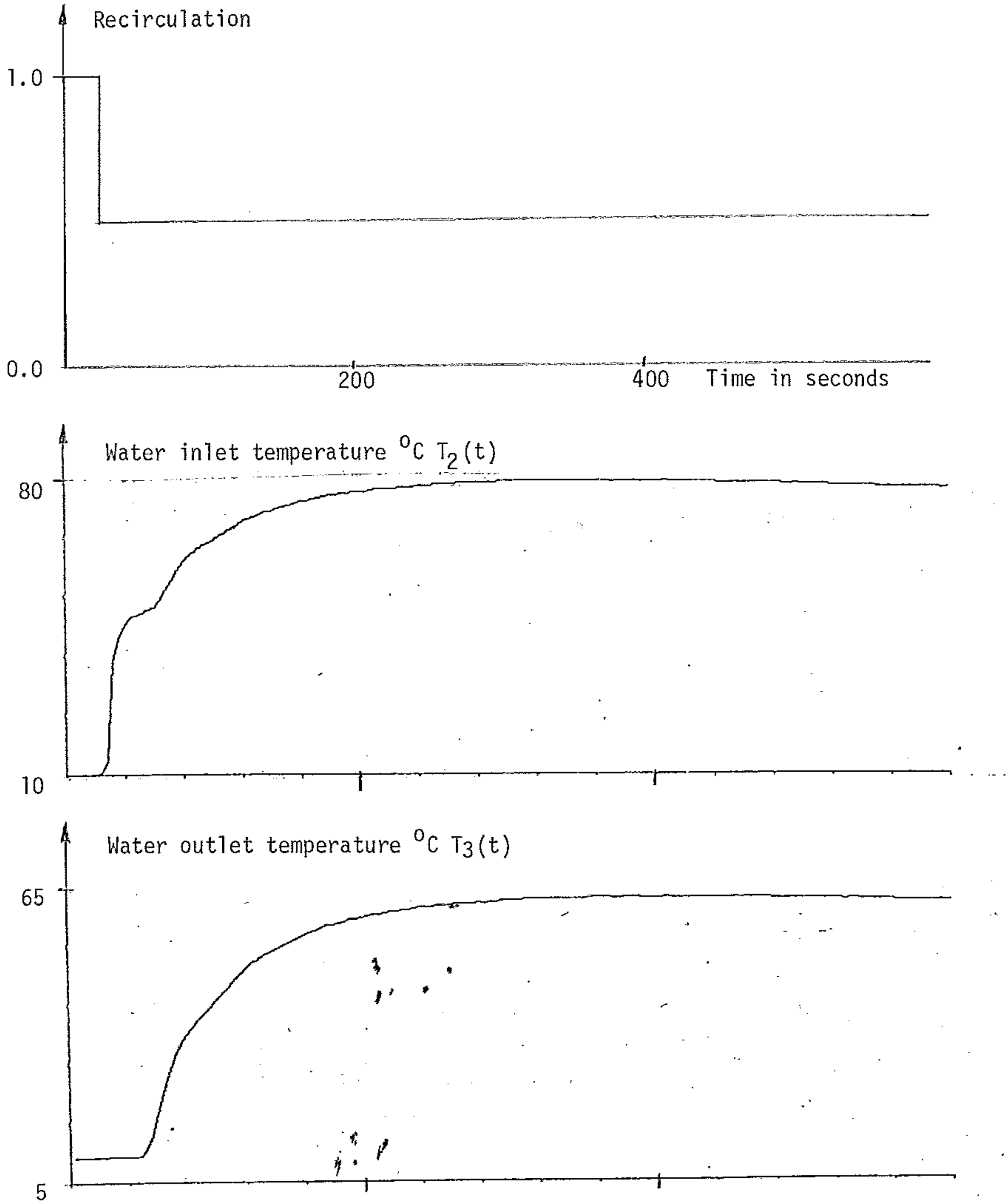

Figure 3.3 Experiment 3

4 References

Jensen, L.H., 1971, Mätningar på luftkonditioneringsanläggning med återblandning. Identifiering av delsystem (in Swedish). (Institutionen för Reglerteknik, Lunds Tekniska Högskola) Report RE-92. Lund.