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1983

Document Version:
Publisher's PDF, also known as Version of record

CODEN:LUTFD2/(TFRT-7262)/1-026/(1983)

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OCTOBER 1983

LUND INSTITUTE OF TECHNOLOGY
DEPARTMENT OF AUTOMATIC CONTROL
Box 725
S 220 07 Lund 7 Sweden

Document name
Technical report

Date of issue
83.10.31

Document number
CODEN:LUTFD2/(TFRT-7262)/1-026/(1983)

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Title and subtitle
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Key words
Modeling, simulation. heat-transfer, thermal stone-beds, reactor dynamics, accident management, steam-condensation.

Classification system and/or index terms (if any)

Supplementary bibliographical information

ISSN and key title

ISBN

Language
English

Number of pages
26

Recipient's notes

Security classification
Yes

Distribution: The report may be ordered from the Department of Automatic Control or borrowed through the University Library 2, Box 1010, S-221 03 Lund, Sweden, Telex: 33248 lubbis lund.

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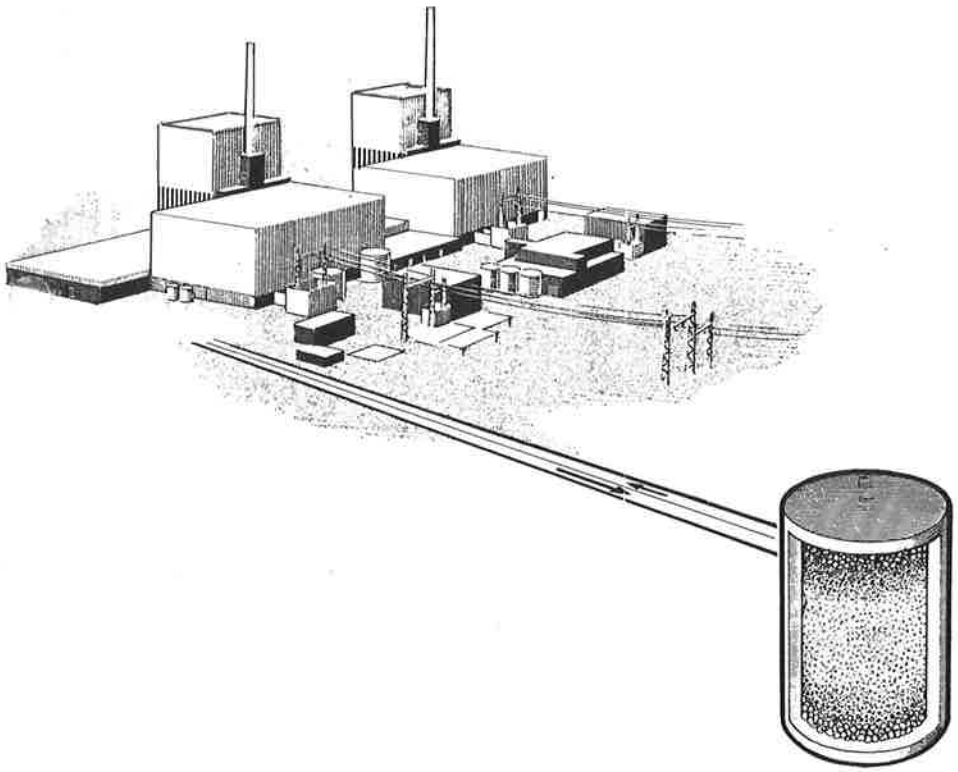

Abstract

The dynamics of a packed-bed thermal stone-condenser (FILTRA) during a reactor accident is described and analyzed. Various aspects on modeling the different subsystems are given and discussed. A simulation model described in the SIMNON model language was developed. The condenser and containment models was partly validated against other simulations and experiments. Model simulations were made for a test case assuming two different protection valve sizes.

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1 PROBLEM FORMULATION.

According to a decision of October 1981 by the Swedish government, equipment for filtered venting of the reactor containments must be installed at the Barsebäck Nuclear Power Station and brought into operation before September 1986. The design of a stone condenser is currently under work in the FILTRA project. However, a question concerning the condenser protection has been formulated, and suggestions for making a simulation study has been discussed. The particular goal of this study was to model and simulate the global dynamics after a severe reactor accident, and analyze the effect of different valves for the stone condenser protection.

2 MODELING.

In order to study the dynamics and main characteristics of the reactor plant during an accident a mathematical model has been developed. The case that should be assumed is characterized by an initial inner reactor isolation, where normal operation of all systems are expected, except that the control rods totally or partly not could be injected. Various simplifications have been made, and in general, point dynamics assumed. However, the energy storage of the stone condenser is characterized by a transport phenomenon and the partial differential equations have therfore been transformed into ordinary differential equations by axial discretization. Four nodes was assumed to be sufficient for the stone condenser. To get a reasonable simple model the following assumptions were made:

1. The stones in the condenser is heated only by condensing steam and saturated water coming from the nodes above. A homogeneous flow is assumed and a ficitve time delay introduced, representing the water film buildup on the stones.

2. The stones can be represented by heat capacity only. No heat conduction within the stones were assumed. This because of the small time constants for the stones (30 sec).

3. No pressure gradient in the stone condenser was assumed.

4. The steam condensation is assumed to be goverened by a simplified static model and depends only on the temperature gradient between the steam and the stones. It was also assumed that when the steam passes through the nodes the steam temperature at the node outlet equals the stone temperatures.

5. When the stone temperatures exceeds the steam temperature flashing is assumed to occur.

6. The steam supported to the reactor containment pool is assumed to condense with a rate proportional to the steam and pool temperature difference. A simplified boiling model was also assumed, including a smooth switching between subcooled and bulk boiling.

7. The reactor is modelled as static with an maximum operating power level proportional to the number of not injected control rods and with a dynamic correction with respect to the Xenon buildup after the power reduction. The water mass in the reactor is modelled as two interconnected tanks. When the tank representing the outer volume (downcomer) is emptied, the reactor power calculation model switches and steam production is assumed to be balanced by the feedwater inlet flow. However, limitation is made with respect to heating of the cooler feedwater and available power.

8. No heat transfer is assumed to the containment and stone condenser walls.

9. The emergency cooling system (323) and steam relief system (314) are modelled as static systems. The reactor dome pressure is modelled as one pressure node in the pressure vessel.

2.1 Stone-condenser modeling

A packed-bed thermal storage system such as the FILTRA stone condenser

consists of a cylindrical unit with a volume of 10000 m^3, a diameter of 20 m and a height of 40 m, packed with stone pebbles of approximately 25-35 mm diameter (See Fig 1). Such a storage system serves two goals. First it represents an increased thermal inertia of the reactor system. Second it enables the capture of radioactive fission fragments, so the exposure to the surrounding during a severe reactor accident could be minimized. A packed stone-bed normally operates in two modes. A charge-mode when enegy is supported from condensing steam and the the stone-bed temperature increases and a discharge-mode where energy is retransferred to the steam from the stones. The dynamic response of packed-bed storage systems have been addressed in a number of papers. (See e.g Saez and MacCoy (1982) and Coutier and Farber (1982)).

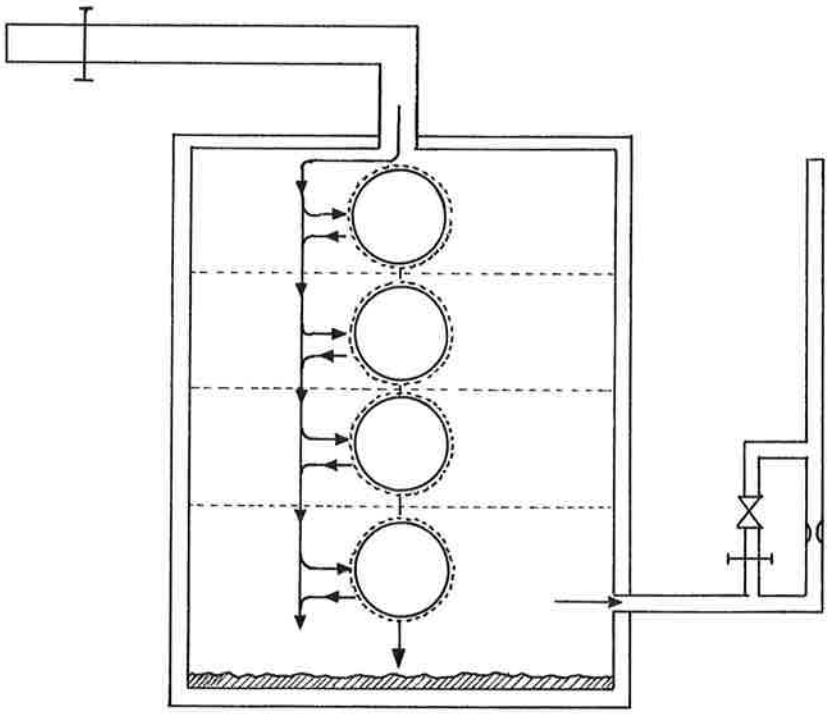

Fig 1 The Barsebeck stone-condenser unit (FILTRA)

Generally the dynamics describing the steam temperature in a distributed system can be represented by the partial differential equation:

$$\varepsilon\varrho c_p\left(\frac{\partial T(z,t)}{\partial t} + v\,\frac{\partial T(z,t)}{\partial z}\right) = k_z\,\frac{\partial^2 T(z,t)}{\partial z^2} - A_s h_c\left(T(z,t) - T_s(t)\right)$$

and the radial temperature dynamics of spherical stone-pebbles by the heat conduction dynamics:

$$\varrho_s c_{ps}\left(\frac{\partial T_s}{\partial t}\right) = k_s\,\frac{1}{r^2}\left(r^2\,\frac{\partial T_s}{\partial r}\right)$$

Assume now that the thermal diffusion could be neglected. The steam temperature distribution is the simply given by the steam velocity, the temperature gradient and the heat transfer to the stone-pebbles. A further assumption concerning the heat transfer to be effecient (which e.g. can be remedied by the large exposed thermal area) gives the steam temperature equal or close to the stone temperature. When the stones in the condenser column are heated, the condensation effeciency becomes lower. This enables the steam to pass to the next node. However, with a temperature given by the stones in the previous node.

The four-node model of the stone condenser is described by the following equations. The steam flow into the first node is represented by a static friction term as:

$$\Phi_1 = \sqrt{\frac{P_s - P_c}{k_{in}}\,\frac{\varrho_s(P_s)}{\varrho_0}}$$

where P_s is the pressure in the reactor containment, P_c the stone condenser pressure and k_{in} represents a friction factor of the condensor inlet tubing. To simulate the function of the containment rupture disc the condenser inlet flow (Φ_1) is set equal to zero until the pressure in the containment reaches a certain limit (0.65 Mpa).

The condensing rate in the nodes is assumed to follow the relation:

$$\Phi_{ci} = k\cdot(T_i - T_{i-1})^{\alpha}$$

The background of this relation is the theory for condensing of steam on vertical surfaces. See e.g Nusselt (1916) and Butterworth (1983). The condensing rate on the suface of a vertical cylinder (with the height L and the diameter D) is given by the relation:

$$\Phi_{c0} = 0.943 \cdot \left[\frac{\lambda^3 \varrho (\varrho - \varrho_s) g}{h_c^3 \eta L} \right]^{0.25} \cdot (T_{sat} - T_w)^{0.75} \cdot \pi DL =$$

$$= k_0 \cdot (T_{sat} - T_w)^{0.75}$$

where λ is the heat conductivity of water, ϱ the density of water, ϱ_s the density of steam, g the acceleration of gravity, h_c the condensation enthalpy of water, η the viscosity of water, T_{sat} the temperature of the saturated steam and T_w the temperature of the wall. However, this formula assumes a smooth vertical surface for the water to condense on and a perfect heat transfer from the water to the wall. In the case of a stone-bed we do not have smooth cylinders, but rough spheres, and the heat transfer from the water to the stones is not perfect. This imply that the effective condensing rate Φ_c is smaller than the theoretically computed rate Φ_{c0}. From the experiments it was found that a reasonable value of k is $0.15 \cdot k_0$.

The flow out of the stone condenser is described by:

$$\Phi_{out} = \sqrt{\frac{P - P_{out}}{k_e} \frac{\varrho (P)}{\varrho_o}}$$

where P_{out} is the atmospheric pressure, P_c the condenser pressure and k_e is an effective friction constant, given by:

$$k_e = \frac{k_1 \cdot k_2}{k_1 + k_2}$$

Here k_1 represents the nominal outlet restriction and k_2 the fictive valve friction activated by the condenser rupture disc at (0.4 Mpa).

Up to a certain amount the condensed water is trapped as a waterfilm covering the stones in the nodes. The Karlshamns experiments reports as much as 25 %. According to these experiments, 1 m^3 of a stonebed, containing

stones with a mean diameter of 35 mm and a void fraction of 0.58, 18 kg of water can be trapped on the surfaces of the stones. This means that when the waterfilm is more than 0.3 mm, the condensed water runs down to the nodes below and no more water is accumulated in that node. The amount of water in node i is denoted M_i. The flow of water from node i to node i+1 is named $\Phi_{wo,i}$. The water mass balance for node i gives:

$$\frac{dM_i}{dt} = \Phi_{c,i} - q_{wo,i} + q_{wo,i-1}$$

Assumption 1 gives the heat balance for the nodes

$$\tau \frac{dT_i}{dt} = (h_c \Phi_{ci} + c_{pw}(T_{s,i-1} - T_{s,i}) \cdot q_{wo,i-1})$$

$$\tau = c_{ps} M_{sti} + c_{pw} M_i$$

where M_{sti} is the stone mass of node i, c_{ps} the heat capacity of stones and c_{pw} the heat capacity of water. The trapped water in the first nodes represents a heat capacity of only a few percent of the stone heat capacity while in the bottom node it can be more than 25 % . The pressure in the stone condenser can be described by the mass balance equation for the steam as:

$$V \frac{\partial \varrho_s}{\partial p} (1-\varepsilon) \frac{dp}{dt} = (\Phi_1 - \Phi_o - \Sigma \Phi_{n,i})$$

where ϱ_s is the density of the steam, ε is the stone void fraction and V is the total gas volume of the stone condenser.

The net steam production Φ_n depends both on the condensing and flashing steam as $\Phi_n = \Phi_f - \Phi_c$. The flashing steam is further given by the simple model:

$$\Phi_f = C_f (T_i - T_{i+1})$$

where C_f is a suitable constant and T_i the node temperatures. In the SIMNON model the vaiables are limited, for example the condensing rate in a node cannot become greater than the flow into the node (See Appendix 7.2).

2.2 Pressure supression modeling

The pressure supression containment (PS) is designed as an internal cylindrical building which contains the reactor vessel and primary systems. During an reactor accident it can be isolated and the environment protected from radioactive contamination. In Fig 2 a simple model of the pressure supresssion containment is presented.

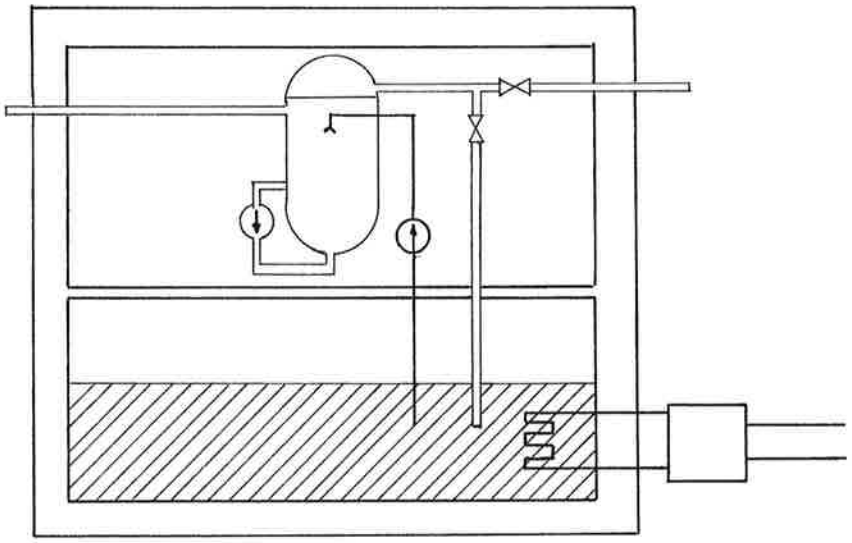

Fig 2 Model of the pressure surpression (PS)

The steam flow ,Φ_{prod} comes from the reactor and is led down through the water in PS. The condensing rate is simplified to:

$$q_{cs} = C_c(p_r - p_{s,sat})\ \Phi_{prod}$$

where p_r is the presure of the steam from the reactor, $p_{s,sat}$ is the saturation pressure and C_c is a constant. Usually $q_{cs}=\Phi_{prod}$ i.e. the steamflow condenses completely. The temperature in PS is T_{ps}, the pressure is p_s and the water mass in PS is m_{ps}. The flow of steam leaving the water in PS due to

boiling is Φ_{bs}. A simple model for this boiling is given by

$$\Phi_{bs} = k_{bo}(1 + \Delta T/35)^{0.75} \qquad \Delta T > 35$$

$$\Phi_{bs} = 0 \qquad \Delta T < 35$$

where $\Delta T = T_{ps} - T_{ps,sat}$

The energy balance of the water gives

$$\frac{dT_{ps}}{dt} \cdot m_{ps}\, c_{p,w} = h_c(q_{cs} - q_{bs}) - W_{out}$$

where W_{out} is the energy removed by the containment cooling system

$$W_{out} = Q_{c32}\,(T_{ps} - T_{sea})$$

Massbalance for the water gives

$$\frac{dm_{ps}}{dt} = q_{cs} - q_{bs}$$

The equation for the pressure in PS becomes

$$V\,\frac{\partial \varrho_s}{\partial p}\frac{dp_s}{dt} = (\Phi_{prod} - q_{cs} + q_{bs} - \Phi_1)$$

When P_s becomes greater than 0.65 Mpa the steam starts to flow through a rupture disc via a pipe leading to the stone condenser.

2.3 Nuclear reactor modeling

One essential part in describing the dynamics of e.g. the PS-condenser pressure is the reactor and the steam production capability. The dynamics of the reactor core is normally described by neutron diffusion and two phase flow dynamics. However, introducing the exact description will yield a model with too much complexity and therefore a simplified approach has been taken

in modeling the steam generation. The reactor system (See Fig 3) can roughly bee seen as two coupled volumes, where the outer one represents the downcomer and the inner one the lower plenum and the core.

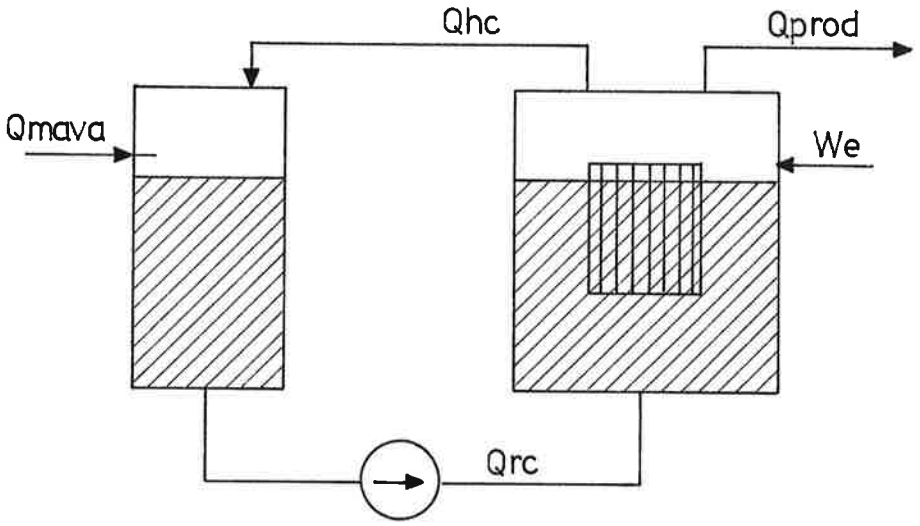

Fig 3 Nuclear reactor model

If we assume that the reactor initially is operating at rated power (1700 MW) and when the transient is applied, reduces to a power level dependent on the circulation flow and the number of control rods that has been injected into the core, we can describe this new operating point as a parameter. As long as there is water in the outer volume the reactor will continue its operation without "knowing" the severness of the transient. However, when the outer volume is empty, power reduction and thus steam reduction follows. A new steady state will occur, where the net inlet water to the outer volume will balance the steam production. However transients in the feedwater flow will be limited by the fact that water must be both heated to saturation and transferred to steam. A limit of the steam production thus follows as

$$\Phi_{smax} = \frac{W_R - q_{fw} c_p \Delta T_1 - q_3 c_p \Delta T_2 - W_{xe} - W_e}{h_c}$$

$$\Phi_{st} = \max (q_{fw}, \Phi_{smax})$$

Where we also have accounted for the core spray flow q_{323} and Xenon power reduction. The time τ_d when the outer volume is emptied can be calculated

from

$$\frac{dV_v}{dt} = - q_{hc} - q_{rc} + q_{fw}$$

$$q_{rc} = q_{hc} - \Phi_{st}$$

$$V(\tau_d) = 0$$

Due to the stored internal heat in the vessel and internal components, an exponentally decaying source can also be added to the termal heat production. We have :

$$\frac{dW_e}{dt} = - \frac{W_e}{\tau_e}$$

The dynamics of the Xenon poisoning effect have also been introduced in the model of the thermal power release. The dynamics of I^{135} and Xe^{127} can be described by the coupled dynamics:

$$\frac{dI}{dt} = - \lambda_I I + \gamma_i \Phi(t)$$

$$\frac{dX}{dt} = \lambda_I I - (\gamma_X - \sigma_X X)\Phi(t) - \lambda_X X$$

$$\Delta W_{xe} = - \sigma_x k_x (X - X_0) / \nu$$

where X and I represents the Xenon and Iod concentration respectively and $\Phi(t)$ the nuclear power.

Modeling of the steam relief system (314)

The steam relief system (314) consists of a number of valves, connected to the four main steam lines, for the protection of the reactor vessel. The valves are normally operated only in emergency and then in sequence. In the pressure range 8.5 -7.8 MPa 13 direct opened valves with a capacity of 55 kg/s at 7.0 MPa each are opened. In the pressure range 7.8 - 7.0 MPa 5 valves of 55 kg/s and 2 valves of 23 kg/s are opened. In the case of a forced pressure reduction at e.g extremly low reactor water level, these valves are also operated.

The steam flow through the pressure relief system can be modelled as:

$$\Phi_{314} = k_{314}(P_r)\sqrt{\frac{(P_r - P_s)\,\varrho_s(P_r)}{P_0 \quad \varrho_0}}$$

where k_{314} is a constant, controlled by the sequence logics.

Modeling of the emergency cooling system (323)

Emergency cooling of the reactor is accomplished by the core spray system. Two redundant pump loops are connected between the core and the pressure supression pool (PS). The flow is further restricted by an automatic control system to a maximum of 170 kg/s per loop.

A simple model for the flow balance is given by the relation:

$$\alpha\, n^2 + \beta\, n\, q_3 + \gamma\, q_3^2 - k_3\, q_3^2 = P_r - P_s - \Delta P_{stat}$$

$$q_3 < M\ 170\ kg/s$$

where M is the number of pumps

2.4 Feedwater system modeling

The feedwater to the reactor comes from the turbine condenser T_1 containing at least 200 m^3 of water. The condenser is supplied with water from two othter tanks, T_1 and T_2 each containing 800 m^3. (See Fig 4). The water level in the condenser is controlled by the feedwater logics. If there are water in the tanks T_1 and T_2, the level in the condenser should be between the levels L3 and L4. When T_3 is filled up to L3 the feedwater flow is 350 kg/s until the level in T_3 reaches the level L4 when the feedwater flow decreases to 120 kg/s until T_3 is filled up to L3 again. When there is no more water in T_1 and T_2 the only flow into T_3 is the auxillary feedwater flow.

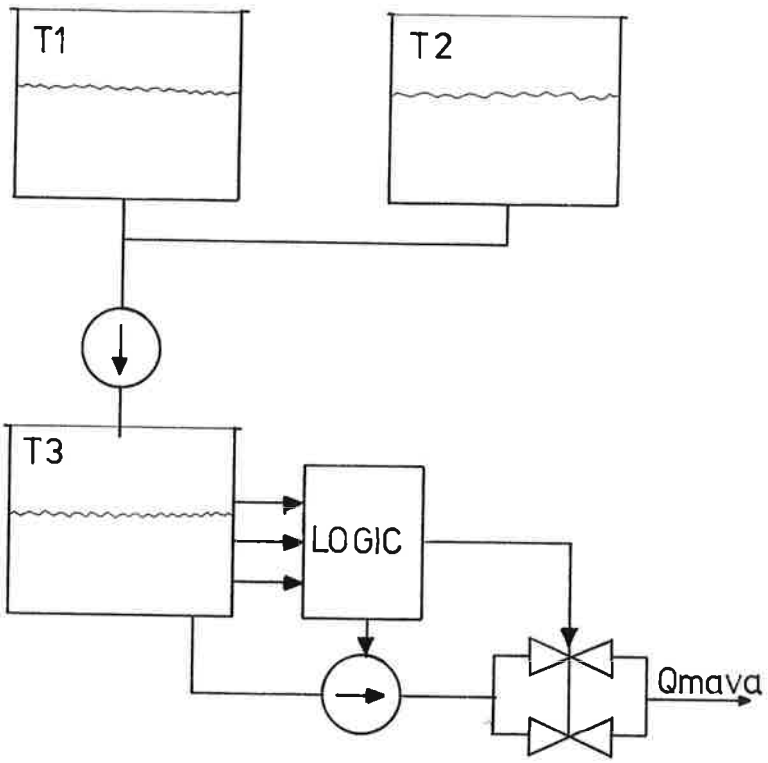

Fig 4 The feedwater system structure

The level in T_1 oscillates between L5 and L4 while the feedwater flow oscillates between 0 and 120 kg/s. (The level L3 is 156 m^3, L4 is 40 m^3 and L5 is 0.7 m^3.) The essential dynamics in this model comes from the control logics which operates the level in the condenser T_3.

3 MODEL VALIDATION.

The simulation model have been tuned against the experiments made at the test facility in Karlshamn. In order to find some of the system parameters, a simplified model describing the experiment was constructed. A ten-node description was made according to Fig 5. (See Appendix 7.2)

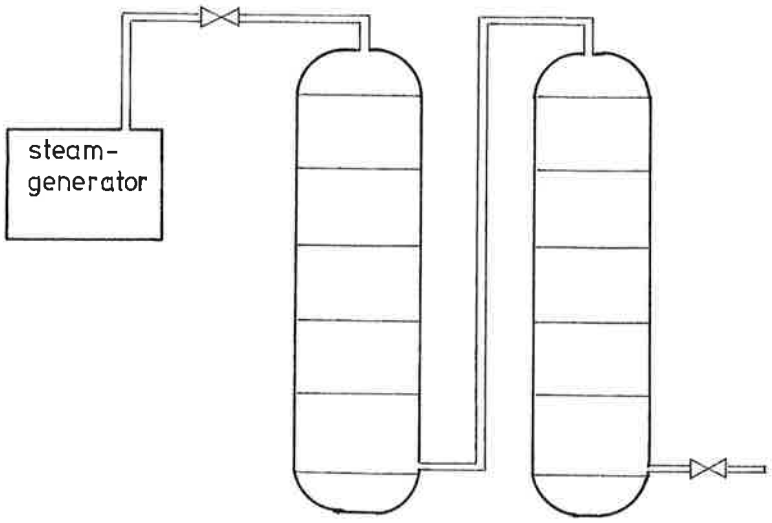

Fig 5 Simplified model of the Karlshamn experiments

The input pressure from the steam generator was given as a simplified linear and exponential decay profile, tuned to approximate the measured pressure. The total amount of water was further obtained by adjusting the inlet and outlet restrictors. A comparison of the generator and stone column pressure is found in Fig 6.

The system parameters of interest: Heat transfer coefficients, condensation and flashing rates, thermal inertia represented by stone void-fraction, inlet and outlet restrictions etc was analyzed with respect to the experiments.

It was found that the theoretical value for the thermal heat conductivity 0.68 had to be adjusted as much as 2000 times to 3.e-4 in order to achive good results. In Fig 6 - Fig 8 the dynamic response of the stone columns can be seen.

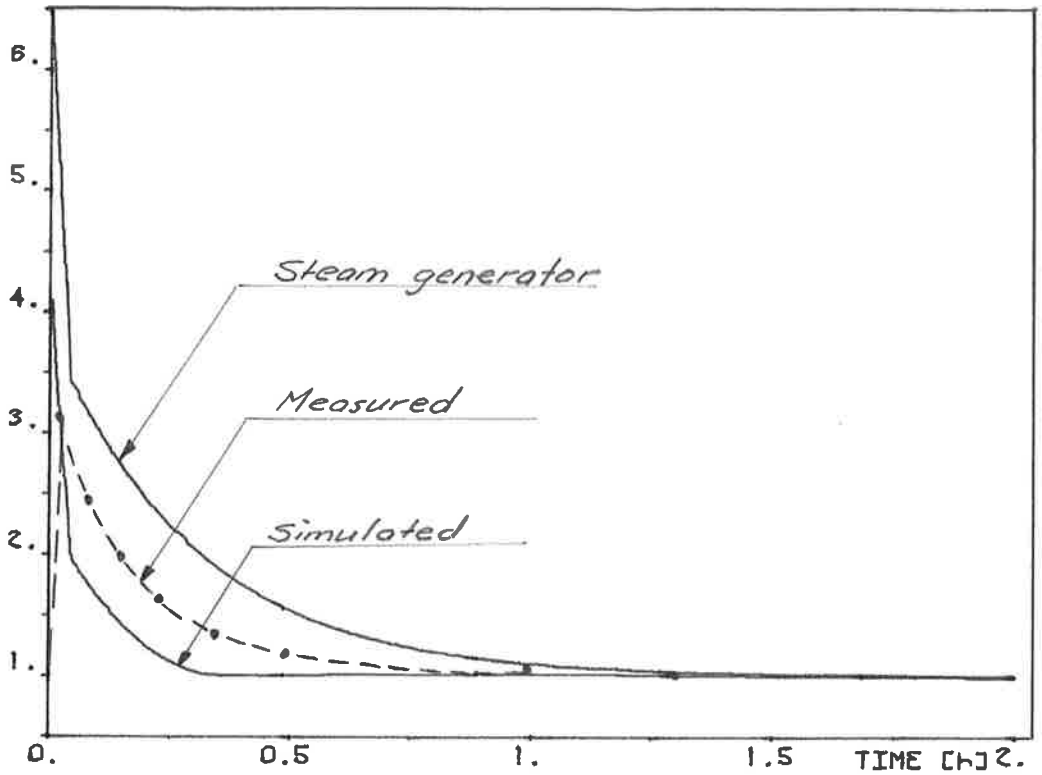

Fig 6 Pressure in the stone bed and in the steam generator.

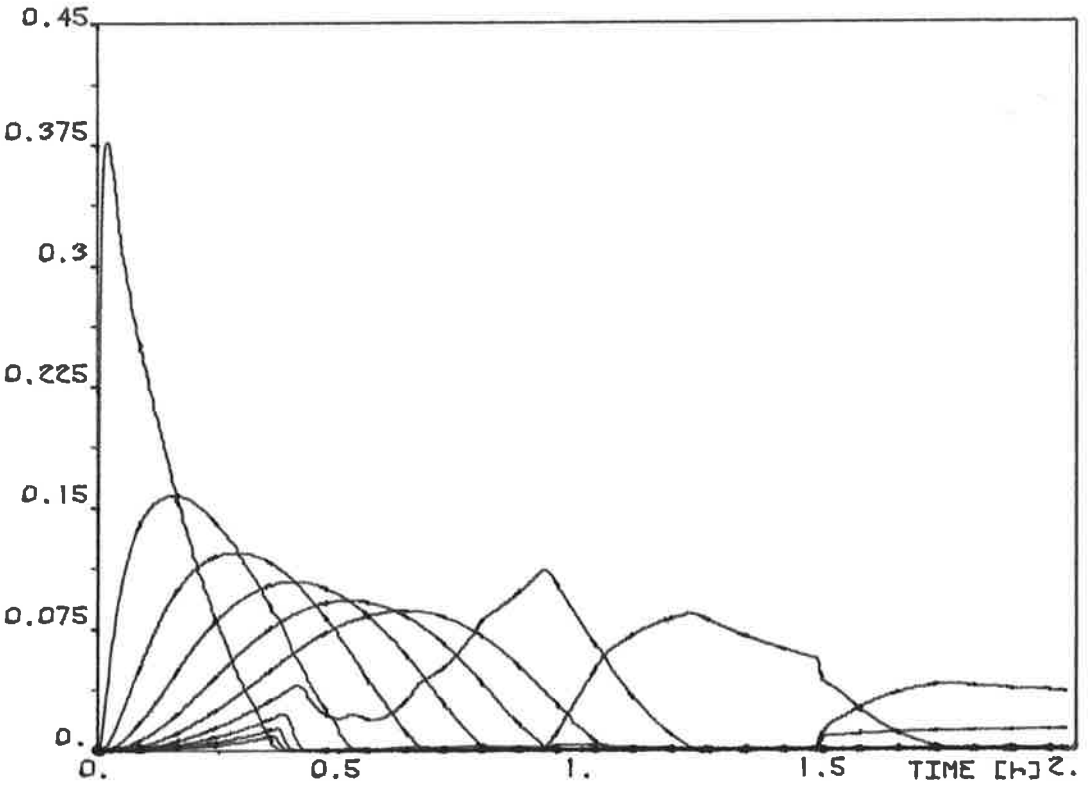

Fig 7 Condensing flow in the nodes.

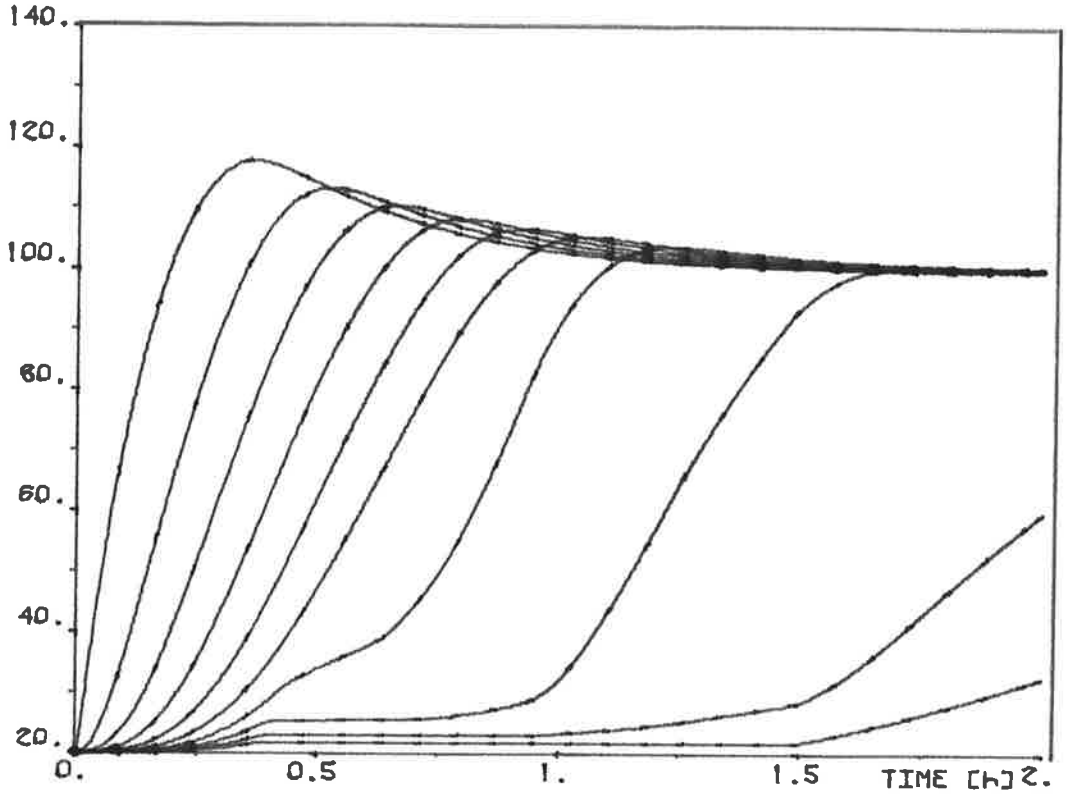

Fig 8 Temperatures in the nodes.

Discussion of the results

From the simulation study of the Karlshamn experiments it was found that the dynamic characteristics of the pressure and temperatures etc could be estimated. However, the heat transfer coefficient λ_w had to be adjusted more than 2000 times. This could perhaps be explained by the reduction in condensing when a non-condensable gas is present. An improvement of the model could therefore be to incorporate the N_2-gas concentration.

4 SIMULATION STUDIES.

Simulations have been carried out in two cases 1) the outlet valve has a capacity of 14 kg/s, and 2) the outlet valve has a capacity of 140 kg/s. There is no cooling of the pressure supression containment, and the reactor is operating at 70% of its maximum level. When the simulation starts the systems FILTRA, mava and PS is in the following states

pressure:	1.0 bar
stone temperature:	20 °C
water temperature:	20 °C
water volume in T_1:	200 m^3
water volume in T_2:	800 m^3
water volume in T_3:	800 m^3

Table 1 Initial values for simulation case 1

As a result of the simulations the following variables are shown in the two cases presented above: FILTRA and PS pressure, in and out flow in FILTRA, stone temperatures in FILTRA and water mass in FILTRA and PS. Curves of the feedwater flow and the flow of steam out of the reactor are also shown.

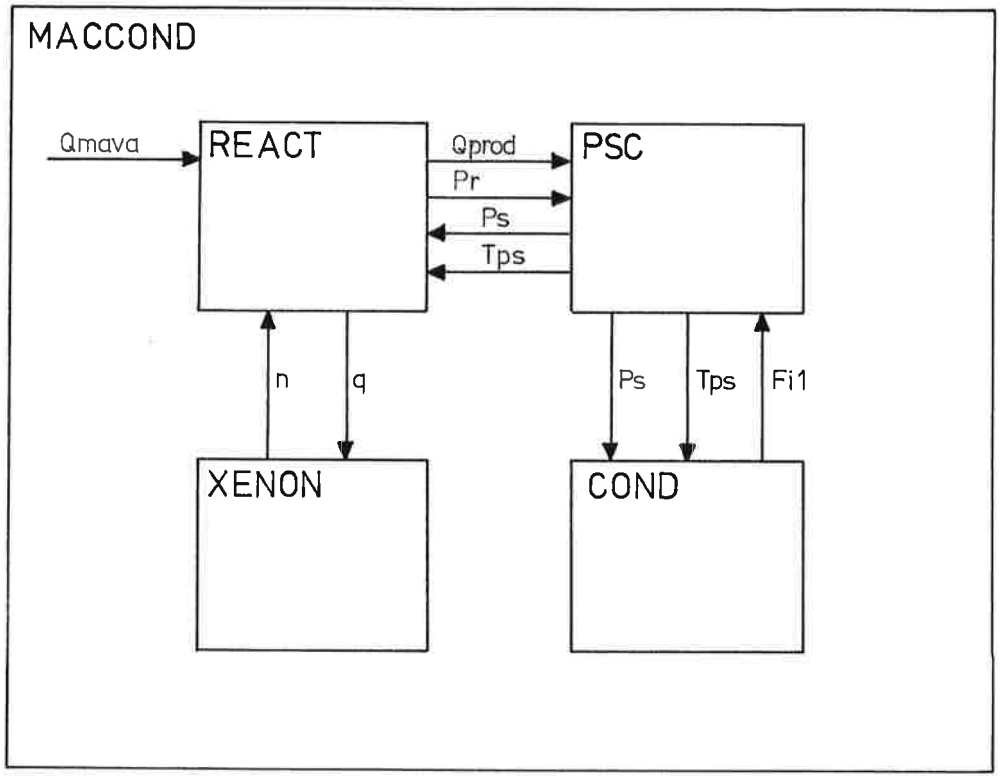

Fig 9 Simulation model structure

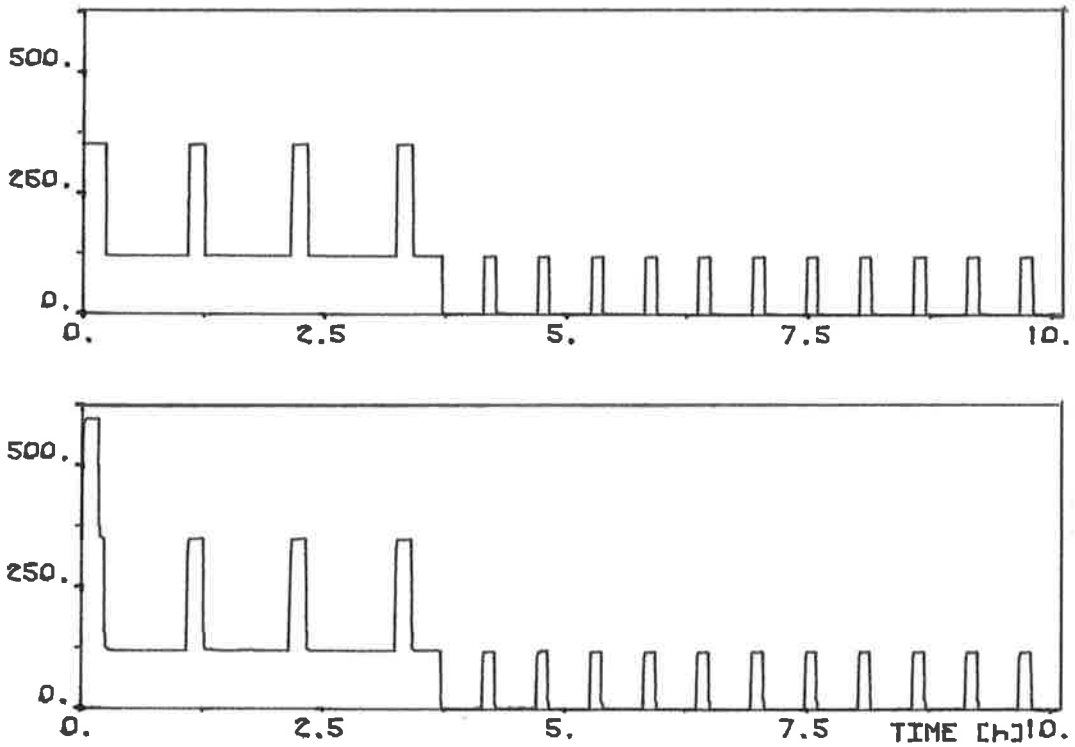

Figure 10 Feedwater flow and steam flow from the reactor.

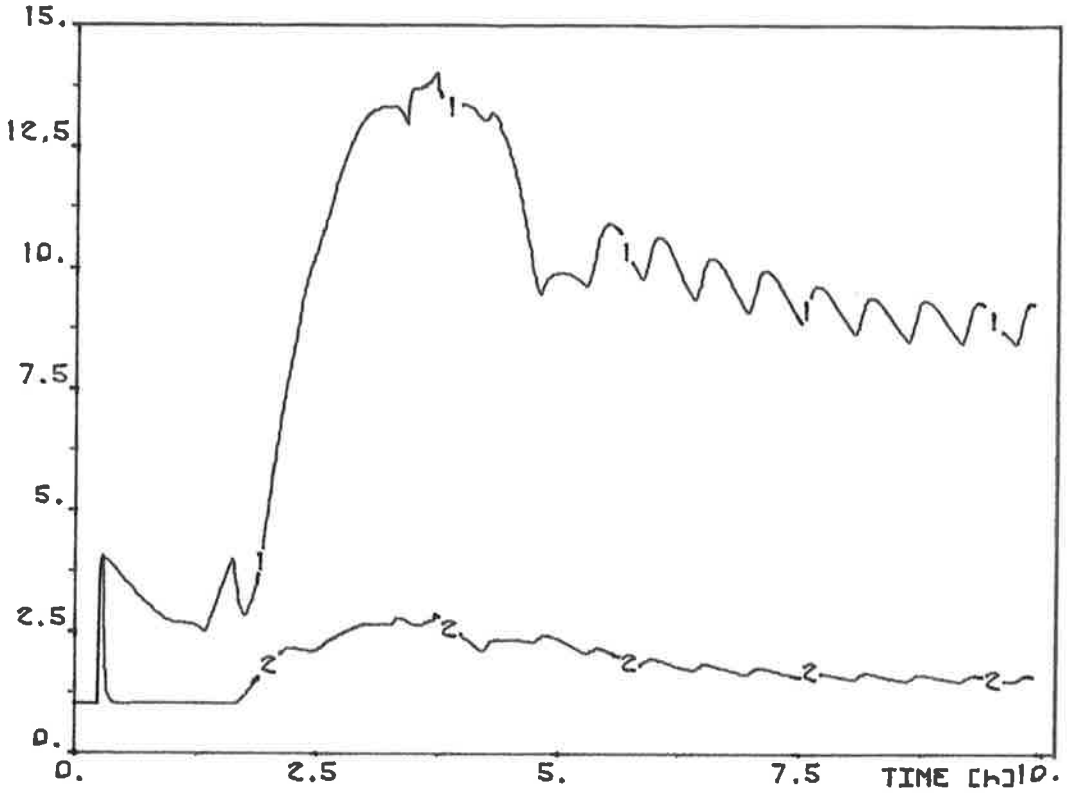

Figure 11 FILTRA pressure. Valve: 1) 14 kg/s 2) 140 kg/s.

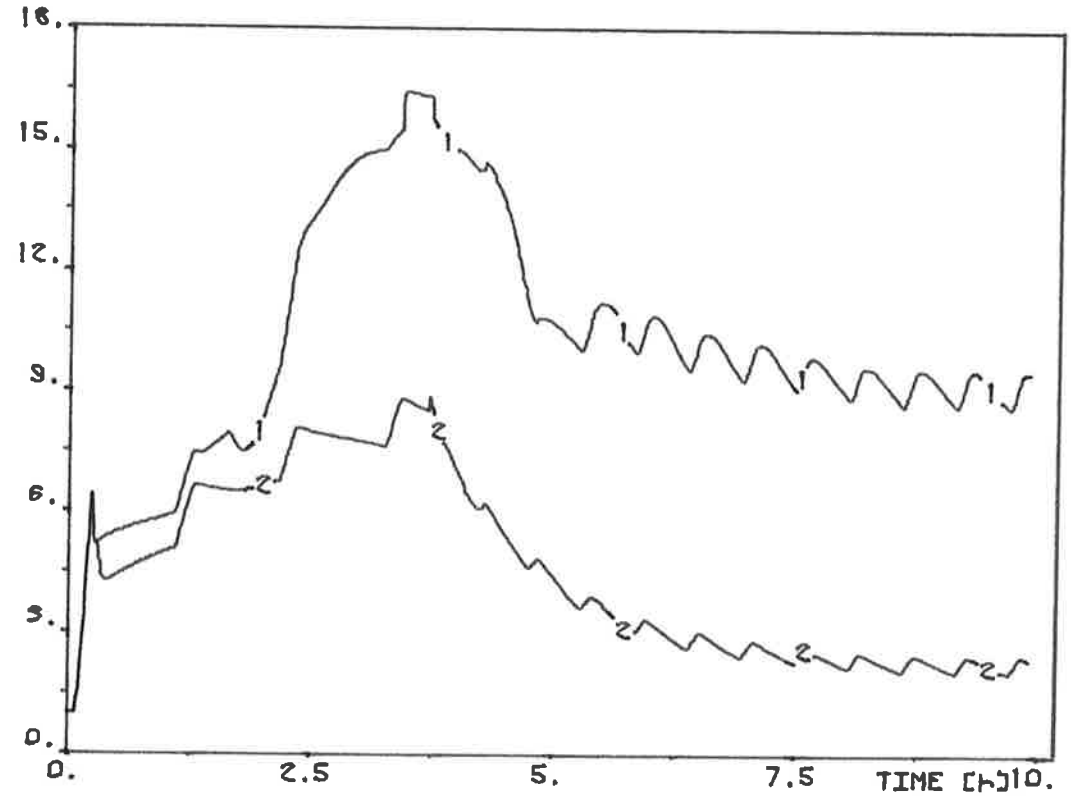

Figure 12 PS pressure. Valve: 1) 14 kg/s 2) 140 kg/s.

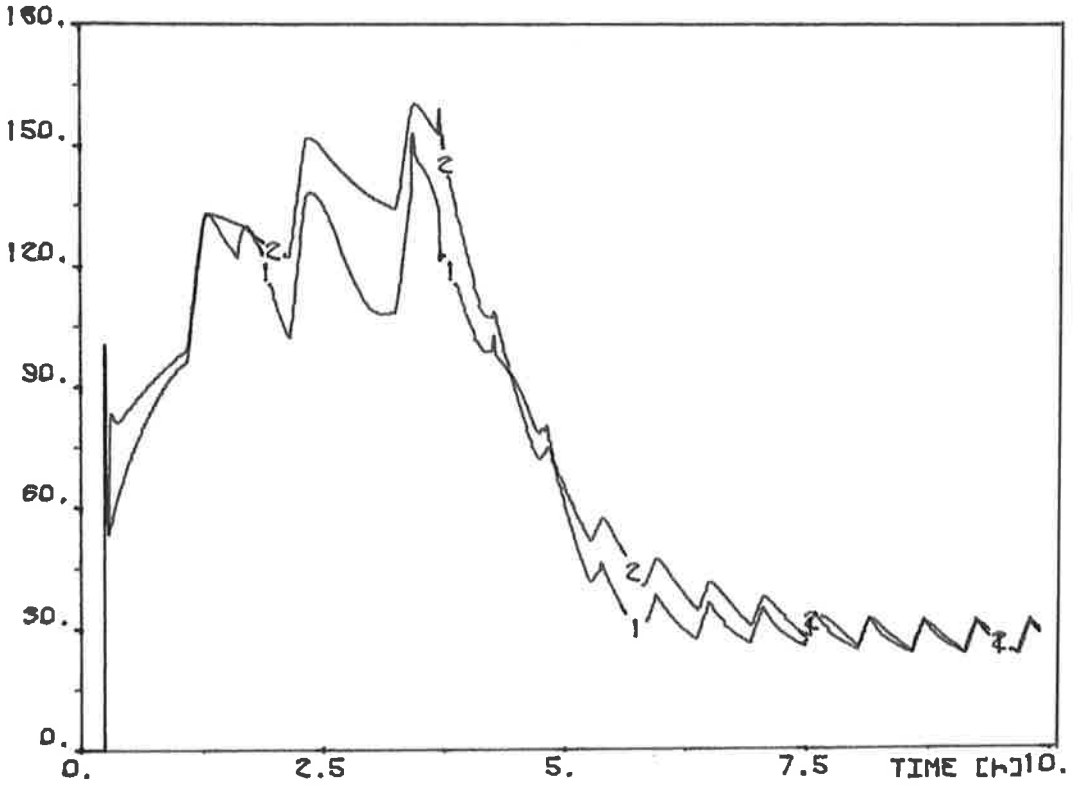

Figure 13 In-flow to FILTRA. Valve: 1) 14 kg/s 2) 140 kg/s.

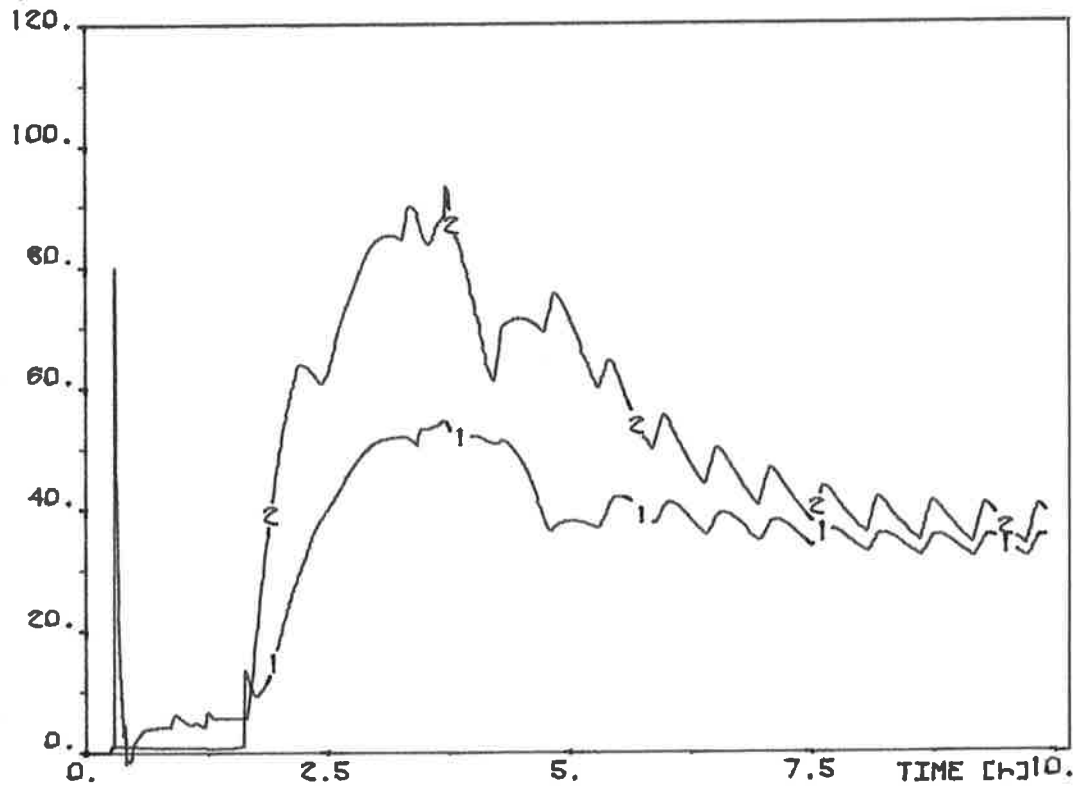

Figure 14 Out-flow from FILTRA. Valve: 1) 14 kg/s 2) 140 kg/s.

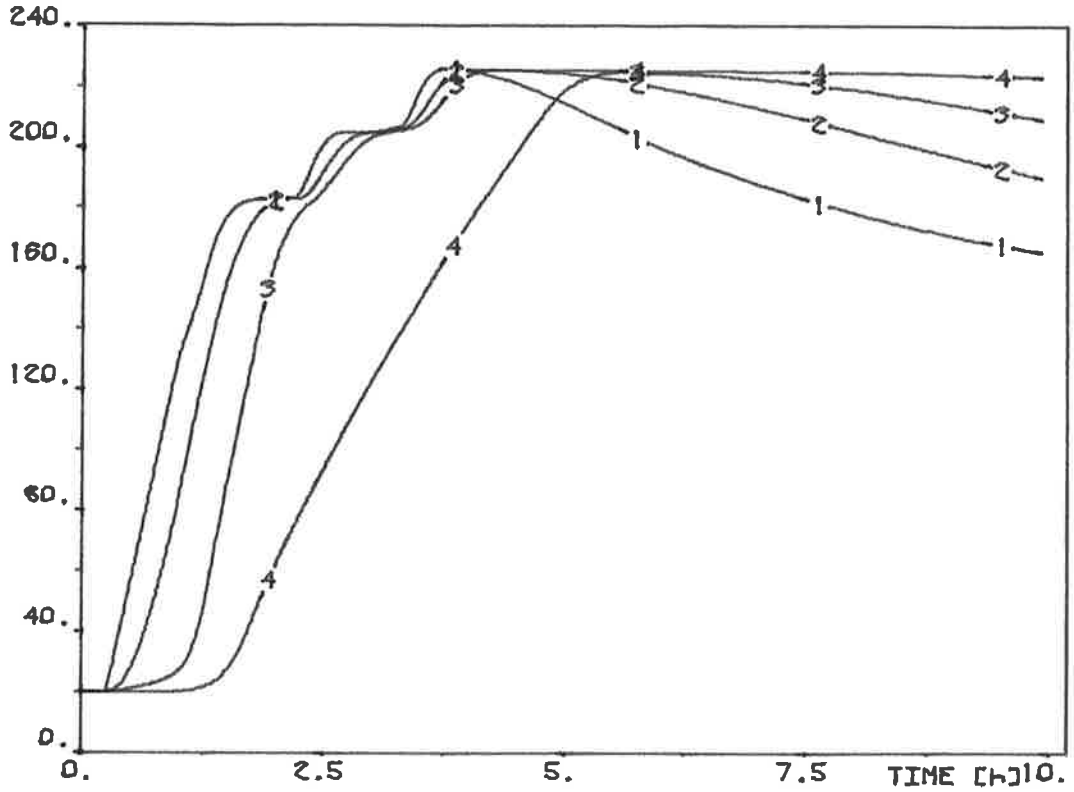

Figure 15 Stone temperatures in FILTRA. Valve: 14 kg/s.

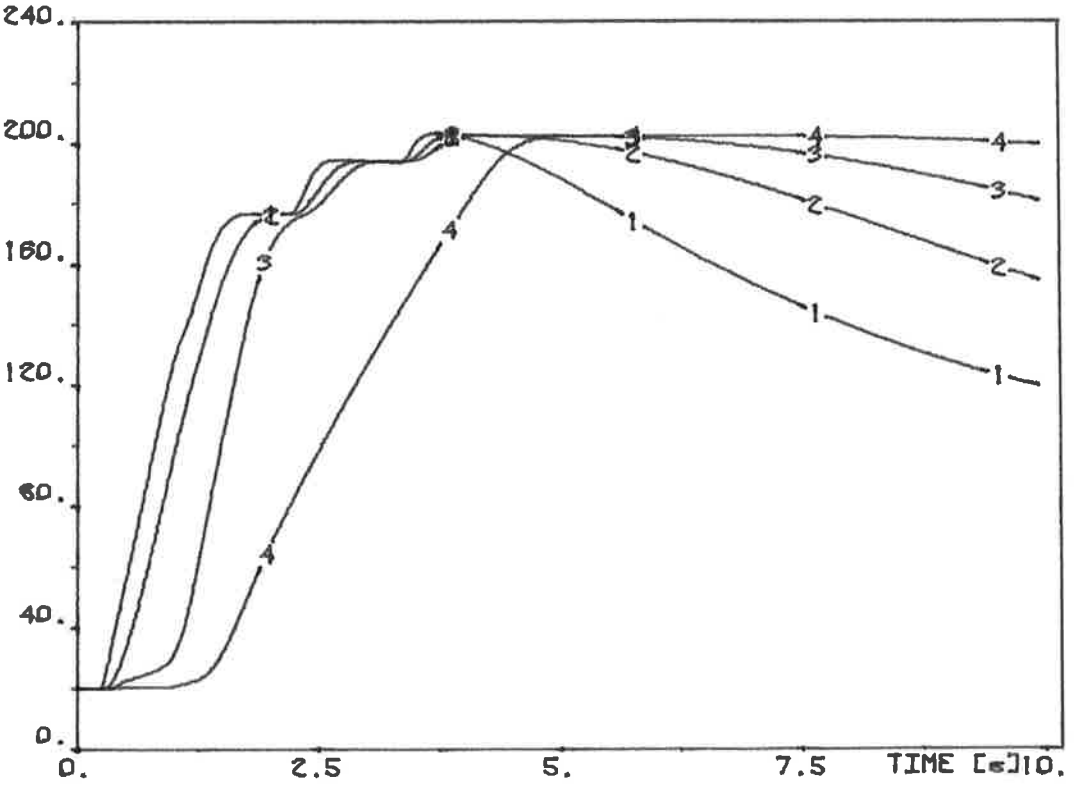

Figure 16 Stone temperatures in FILTRA. Valve: 140 kg/s.

5 CONCLUSION.

A simulation model describing the dynamics of the Barsebäck nuclear power plant during a reactor accident has been constructed. The model was developed in a modular and structured way, using the SIMNON simulation package. Systems like the feedwater process, the nuclear reactor, the pressure relief system etc, were represented together with the dynamics of the stone-condenser (FILTRA). System parameters were partly validated against the Karlshamn experiments performed in 1981. A test simulation case was performed with the entire model, representing a dimensioning situation where no control rods could be injected. Two different outlet valve sizes were investigated. The results show that in the case of a small valve (14 kg/s) condenser over-pressure exceeds in 1.5-2.5 hours. In the case of a larger valve (140 kg/s) this time is between 2.5-5 hours.

Because of the complicated thermodynamical heat transfer and transport in the stone-condenser together with the many assumptions and e.g simplified reactor modelling, much care must be taken when interpreting the results. However, the parameter dependencies and global dynamic behaviour is assumed, at least to the order of magnitude, represent the physical behaviour under the postulated conditions.

6 REFERENCES

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APPENDIX
Nomenclature

Φ_i	steam flow into node i	[kg/s]
$\Phi_{c,i}$	condensing rate in node i	"
$\Phi_{wo,i}$	flow of water from node i	"
Φ_o	steam flow out of FILTRA	"
Φ_{st}	produced steam flow	"
Φ_{smax}	maximum steam flow rate	"
p_s	PS pressure	[bar]
p_{out}	atmospheric pressure	"
Qr	reactor power	[W]
P_r	pressure in the reactor	[bar]
$P_{s,sat}$	saturation pressure in PS	"
$T_{s,i}$	stone temperature in node i	[°C]
T_{ps}	temperature in PS	"
T_{sea}	sea temperature	"
k_1	valve constant	[bar/(kg/s)2]
k_2	valve constant	"
k_i	valve constant	"
M_i	water mass in node i	[kg]
$M_{st,i}$	stone mass in node i	"
M_{ps}	water mass in PS	"
$c_{p,st}$	heat capacity of stone	[J/(kg°C)]
$c_{p,w}$	heat capacity of water	"
h_c	condensing enthalpy of steam	[J/kg]
ϱ	density of steam	[kg/m3]
V	FILTRA volume	[m3]
ε	void fraction in FILTRA	[pu]
q_{cs}	condensing rate in PS	[kg/s]
q_{bs}	boiling rate in PS	"
q_{323}	spray flow in the reactor	"
q_{hc}	circulation pump flow	"
q_{rc}	recirculation flow	"
q_{fw}	feedwater flow	"
W_{out}	heat flow out of PS	[W]
V_v	reactor volume	[m3]
Q_e	energy stored in the reactor	[J]

APPENDIX
Nomenclature

```
CONTINUOUS SYSTEM COND
"
"FILE: COND.T
"
"Description:    A mathematical model of the FILTRA
"                stone-condenser.
"
"Author:         S.Bergman
"                P.Persson
"
INPUT ps tps
OUTPUT fi1
"
STATE  bl  cl ts1 ts2 ts3 ts4  m1  m2  m3  m4
STATE  p f1 f2 f3 f4
DER   dbl dcl ds1 ds2 ds3 ds4 dm1 dm2 dm3 dm4
DER dp df1 df2 df3 df4

" bl cl          Flags for rupture-discs
" ts1..ts4       Node temperatures in nodes 1..4
" m1..m4         Water mass in nodes 1..4
" fic1..fic4     Condensing rate in nodes 1..4

a1 = Vtot*(1 - eps)*drdp
ke = k1*k2/(k1 + k2)

"THE RUPTURE DISC LEADING INTO FILTRA

dbl = if ps>pslim then (if bl<1 then 10000 else 0) else 0
bleck = if bl>0 then 1 else 0
fi1x = sign(ps - p)*sqrt(abs(ps - p)*0.5*ps/(kin*3.25))
fi1 = if bleck then fi1x else 0

"PRESSURE IN FILTRA

dp = (fi1 - sfic + sfif - fio)*Tscal/a1
sfic = fic1 + fic2 + fic3 + fic4
sfif = fif1 + fif2 + fif3 + fif4

"STEAM FLOW INTO THE NODES

fi2 = max(fi1 - fic1 + fif1,0)
fi3 = max(fi2 - fic2 + fif2,0)
fi4 = max(fi3 - fic3 + fif3,0)

"THE RUPTURE DISC LEADING OUT OF FILTRA

dcl = if p>pclim then (if cl<1 then 10000 else 0) else 0
bleck1 = if cl>0 then 1 else 0
k2 = if bleck1 then k2x else 1000000*k2x
fio = sign(p - pout)*sqrt(abs(p - pout)*0.5*p/(ke*2))

"MASS BALANCE EQUATIONS

dm1x = (fic1 - fiwo1 - fif1)*Tscal
```

APPENDIX
SIMNON code

```
dm2x = (fiwo1 + fic2 - fiwo2 - fif2)*Tscal
dm3x = (fiwo2 + fic3 - fiwo3 - fif3)*Tscal
dm4x = (fiwo3 + fic4 - fif4)*Tscal

dm1  =  if m1<wlim then (if m1>0 then dm1x else 0) else 0
dm2  =  if m2<wlim then (if m2>0 then dm2x else 0) else 0
dm3  =  if m3<wlim then (if m3>0 then dm3x else 0) else 0
dm4  =  if m4>0 then dm4x else 0

" THE CONDENSING RATE IN THE NODES

N = 2*V*eps/(3.14*r*D*D)
xx=0.943*3.14*D*L
new = xx*(lambdaw^3*rol*(rol - rog)*10*dhn/(eta*L))^0.25

tt1 =  if (tps - ts1)>0 then tps - ts1 else 0
zz1 = new*tt1^0.75*N/dhn
fic1x = max(0,min(zz1,fi1))

tt2 =  if (ts1 - ts2)>0 then ts1 - ts2 else 0
zz2 = new*tt2^0.75*N/dhn
fic2x = max(0,min(zz2,fi2))

tt3 =  if (ts2 - ts3)>0 then ts2 - ts3 else 0
zz3 = new*tt3^0.75*N/dhn
fic3x = max(0,min(zz3,fi3))

tt4 =  if (ts3 - ts4)>0 then ts3 - ts4 else 0
zz4 = new*tt4^0.75*N*2/dhn
fic4x = max(0,min(zz4,fi4))

df1 = (fic1x - f1)*Tscal/tauf
df2 = (fic2x - f2)*Tscal/tauf
df3 = (fic3x - f3)*Tscal/tauf
df4 = (fic4x - f4)*Tscal/tauf

fic1 = max(0,min(fcon,f1))
fic2 = max(0,min(fcon,f2))
fic3 = max(0,min(fcon,f3))
fic4 = max(0,min(fcon,f4))

"FLASHING MODEL

fif1 = if tps<ts1 then kfl*(ts1 - tps) else 0
fif2 = if ts1<ts2 then kfl*(ts2 - ts1) else 0
fif3 = if ts2<ts3 then kfl*(ts3 - ts2) else 0
fif4 = if ts3<ts4 then kfl*(ts4 - ts3) else 0

"WATER FLOW OUT OF THE NODES

fiwo1 =  if m1>wlim then fic1 else 0
fiwo2 =  if m2>wlim then fic2 else 0
fiwo3 =  if m3>wlim then fic3 else 0

A = 2*V*eps*gamma*(D/2 + L)/(D*r)
```

APPENDIX
SIMNON code

```
wlim = A*film*row

ms = V*eps*ros
c1 = ms*cps
c2 = 2*ms*cps + m4*cpw

"THE ENERGY EQUATIONS

ds1 = hc*(fic1 - fif1)*Tscal/c1
ds2 = (hc*(fic2 - fif2) + fiwo1*cpw*(ts1 - ts2))*Tscal/c1
ds3 = (hc*(fic3 - fif3) + fiwo2*cpw*(ts2 - ts3))*Tscal/c1
ds4 = (hc*(fic4 - fif4) + fiwo3*cpw*(ts3 - ts4))*Tscal/c2

"Parameters:

hc:         2.1E6      "[J/kgK]
drdp:       0.5        "[kg/(m3 bar)]
row:        1000       "[kg/m3]
cpw:        4.18E3     "[J/kgK]
cps:        800        "[J/kgK]
ros:        2700       "[kg/m3]
Ar:         314        "[m2]
V:          2000       "[m3]
Vtot:       7340       "[m3]
Vx:         200        "[m3]
kf:         100        "
k:          2.257E-5   "[bar/kg2s2]
kin:        3.25E-4    "[bar/kg2s2]
k1:         3.0        "[bar/kg2s2]
k2x:        1.53E-4    "[bar/kg2s2]
r:          0.035      "[m]
film:       0.35E-3    "[m]   Waterfilm
gamma:      0.75       "[pu]
eps:        0.58       "[pu]
pclim:      4.0        "[bar]
Pr:         12.0       "[bar]
Pout:       1.0        "[bar]
Pslim:      6.5        "[bar]
kfl:        1
Tscal:      3600
eta:        0.28E-3    "[Pas]
lambdaw:    0.3E-3     "[W]
D:          0.028      "[m]
L:          0.035      "[m]
rol:        1E3        "[kg/m3]
rog:        20         "[kg/m3]
dhn:        2.1E6      "[J/kg]
tauf:       100        "[s]
fcon:       5          "
c10:        6E-3
c11:        0
c12:        4.25E-5
c20:        2.3557E-1
c21:        -1.3401E-2
c22:        3.22175E-4
```

APPENDIX
SIMNON code

```
c23:        -2.92143E-6
c24:        1.82143E-8
c30:        0.806999
c31:        -3.13358E-2
c32:        5.33437E-4
c33:        -4.15625E-6
c34:        2.2656E-8
c35:        -1.042E-11
d10:        3.8
d11:        799.8
d12:        -4192
d20:        23.6589
d21:        246.1716
d22:        -356.2139
d23:        185.1883
d35:        0.0022
d34:        -0.0862
d33:        1.2729
d32:        -9.2226
d31:        40.5605
d30:        67.1414
"
END
```

APPENDIX
SIMNON code

```
CONTINUOUS SYSTEM REACT

"File: REACT.T
"Author: S. Bergman
"        P. Persson

INPUT Qmava  tps  ps
OUTPUT Qprod

STATE E Wr Pr
DER dE dWr dPr

dE = -E*Tscal/tau
tau = V*row1/(Qmava + 10)
dWr = if Wr>0 then (-Qhc + Qrc + Qmava)*Tscal/row else 0
P = Pre + E/tau
Qp = (P*peff - Cp*Qmava*dT - q323*Cp*(Tc - Tps))/hc
qst = if Wr<0 then max(0,min(Qmava,Qp)) else peff*Qstfull

fav = pr - ps
dPr = (qst - Qprod)*Tscal/T
Qprod = if fav > 0 then sqrt(fav*pr*0.5/(k314*35)) else 0
fac = alfa*n*n - (Pr - Ps) - Hstat
q32 = if fac > 0 then sqrt(fac/kv) else 0
q323 = min(q32,170)

"Parameters:
kv:         3.0E-4
alfa:       1.01784E-5
beta:       -1.05419E-5
gamma:      -2.71429E-4
Hstat:      2.0
n:          1450
k314:       5.68E-4
switch:     1
row:        1E3      "[kg/m3]
row1:       730      "[kg/m3]
Pre:        1700E6   "[W]
Tc:         200      "[deg C]
peff:       0.7      "[pu]
Qstfull:    850      "[kg/s]
Qhc:        2500     "[kg/s]
Qrc:        2000     "[kg/s]
Cp:         4.18E3   "[J/kgK]
dT:         200      "[K]
V:          200      "[m3]
hc:         2.1E6    "[J/kg]
Tscal:      3600     "[s/h]
T:          100      "[s]

END
```

APPENDIX
SIMNON code

```
CONTINUOUS SYSTEM PSC

"File: PS.T

"Author: S. Bergman
"        P. Persson

INPUT Qprod  fi1 pr

STATE  mps tps ps mq
DER dms dts dps dq

"EQUATIONS FOR THE PRESSURE SUPRESSION CONTAINMENT

d1=mps*cpw

s1 = (d12*ps + d11)*ps + d10
s2 = ((d23*ps + d22)*ps + d21)*ps + d20
s3 = ((((d35*ps + d34)*ps + d33)*ps + d32)*ps + d31)*ps
s3 = s3 +d30
ts = if ps<0.074 then s1 else if ps<1 then s2 else s3

e1 = (c12*Tps + c11)*Tps + c10
e2 = (((c24*Tps + c23)*Tps + c22)*Tps + c21)*Tps + c20
e3 = ((((c35*Tps + c34)*Tps + c33)*Tps + c32)*Tps + c31)*Tps
e3 = e3 + c30
prs = if Tps<40 then e1 else if Tps<100 then e2 else e2

dhdps = 1E6*0.174*0.223*ps^(-0.777)
bs2 = dhdps*Cscal2/hc

dms = (qcs - qbs)*Tscal
dts = (qcs*hc - qbs*hc - wout)*Tscal/d1
dps = Tscal*qxs/(Vi*drdp)

qcs = max(min(1,(pr - prs)*bs2),0)*Qprod

"Simplified Boiling model

deltaT = Tps - Ts
qbs = if (1 + deltaT/35)<0 then 0 else kbo*(1 + deltaT/35)^0.75

wout=Qc32*(Tps-Tsound)

qxs =  Qprod-qcs+qbs-fi1
Vi = Vtot - Vc - Vx
dq = qxs*Tscal
pq = mq*Rg*(Tps + 273)/(mH2O*Vi)
Vc = mps/row

"Parameters:

hc:         2.1E6       "[J/kgK]
dhdp:       1E4         "[J/(kg bar)]
kf:         100         "
```

APPENDIX
SIMNON code

```
drdp:       0.5         "[kg/(m3 bar)]
Vtot:       7340        "[m3]
Vx:         200         "[m3]
k:          2.257E-5    "[bar/kg2s2]
kin:        4E-4        "[bar/kg2s2]
Tscal:      3600        "[pu]
Cscal2:     40.0        "[pu]
row:        1000        "[kg/m3]
r:          0.035       "[m]
cpw:        4.18E3      "[J/kgK]
cps:        800         "[J/kgK]
ros:        2700        "[kg/m3]
pclim:      4.0         "[bar]
Pout:       1.0         "[bar]
Pslim:      6.5         "[bar]
k1:         3.0
k2x:        1.53E-4
Tsound:     17          "[DegC]
Qc32:       440E3       "[W/K]
Rg:         8.31E-2
mH2O:       18
kbo:        100
c10:        6E-3
c11:        0
c12:        4.25E-5
c20:        2.3557E-1
c21:        -1.3401E-2
c22:        3.22175E-4
c23:        -2.92143E-6
c24:        1.82143E-8
c30:        0.806999
c31:        -3.13358E-2
c32:        5.33437E-4
c33:        -4.15625E-6
c34:        2.2656E-8
c35:        -1.042E-11
d10:        3.8
d11:        799.8
d12:        -4192
d20:        23.6589
d21:        246.1716
d22:        -356.2139
d23:        185.1883
d35:        0.0022
d34:        -0.0862
d33:        1.2729
d32:        -9.2226
d31:        40.5605
d30:        67.1414
"
END
```

APPENDIX
SIMNON code

```
CONNECTING SYSTEM CONCOND

"File: CONCOND.T
"Author: S. Bergman
"        P. Persson

Qmava[react]=c2[ifile]

Qprod[psc]=Qprod[react]
fi1[psc]=fi1[cond]
pr[psc]=pr[react]

ps[cond]=ps[psc]
tps[cond]=tps[psc]

ps[react]=ps[psc]
tps[react]=tps[psc]

END
```

APPENDIX
SIMNON code

```
CONTINUOUS SYSTEM COND1
"
"FILE: KARL1.T
"
"Description:   A mathematical model of the Karlshamn
"               experiment
"
"Author:        S.Bergman
"               P.Persson
"

STATE t1 t2 t3 t4 t5 m1 m2 m3 m4 m5
STATE p f1 f2 f3 f4 f5 x

DER d1 d2 d3 d4 d5 dm1 dm2 dm3 dm4 dm5
DER dp df1 df2 df3 df4 df5 dx

INPUT pst sfic2 fio tps sfif2
OUTPUT fi5 fic5

TIME t

" t1..t5       Node temperatures in nodes 1..5
" m1..m5       Water mass in nodes 1..5
" p            Pressure
" f1..f5       Condensing rate in nodes 1..5
" x            Total amount of steam

" fi1..fi5     The steam flow into nodes 1..5
" fic1..fic5   The condensing rate in the nodes 1..5
" fiwo1..fiwo5 The water flow out of nodes 1..5

a1=Vtot*(1-eps)*drdp

"PRESSURE IN FILTRA

sfic1 = fic1 + fic2 + fic3 + fic4 + fic5
sfif1 = fif1 + fif2 + fif3 + fif4 + fif5
dp = (fi1 - sfic1 - sfic2 + sfif1 + sfif2 - fio)*Tscal/a1

"STEAM FLOW INTO THE NODES

dx   = fi1*Tscal
fi1x = sqrt(abs((pst - p)*pst/(kin*6)))
fi1  = if pst>p then fi1x else 0
fi2  = max(fi1 - fic1,0)
fi3  = max(fi2 - fic2,0)
fi4  = max(fi3 - fic3,0)
fi5  = max(fi4 - fic4,0)

"MASS BALANCE OF WATER

dm1x = (fic1 - fiwo1 - fif1)*Tscal
dm2x = (fiwo1 + fic2 - fiwo2 - fif2)*Tscal
dm3x = (fiwo2 + fic3 - fiwo3 - fif3)*Tscal
```

APPENDIX
SIMNON code

```
dm4x = (fiwo3 + fic4 - fiwo4 - fif4)*Tscal
dm5x = (fiwo4 + fic5 - fif5)*Tscal

dm1 = if m1 < wlim then (if m1>0 then dm1x else 0) else 0
dm2 = if m2 < wlim then (if m2>0 then dm2x else 0) else 0
dm3 = if m3 < wlim then (if m3>0 then dm3x else 0) else 0
dm4 = if m4 < wlim then (if m4>0 then dm4x else 0) else 0
dm5 = dm5x

"CONDENSATION MODEL

N = 2*V*eps/(3.14*r*D*D)
XX=0.943*3.14*D*L
new = XX*(lambdaw^3*rol*(rol - rog)*10*dhn/(eta*L))^0.25

tt1 =  if (tps - t1)>0 then tps - t1 else 0
zz1 = new*tt1^0.75*N/dhn
fic1x = max(0,min(zz1,fi1))

tt2 =  if (t1 - t2)>0 then t1 - t2 else 0
zz2 = new*tt2^0.75*N/dhn
fic2x = max(0,min(zz2,fi2))

tt3 =  if (t2 - t3)>0 then t2 - t3 else 0
zz3 = new*tt3^0.75*N/dhn
fic3x = max(0,min(zz3,fi3))

tt4 =  if (t3 - t4)>0 then t3 - t4 else 0
zz4 = new*tt4^0.75*N/dhn
fic4x = max(0,min(zz4,fi4))

tt5= if (t4 - t5)>0 then t4 - t5 else 0
zz5=new*tt5^0.75*N/dhn
fic5x = max(0,min(zz5,fi5))

df1 = (fic1x - f1)*Tscal/tauf
df2 = (fic2x - f2)*Tscal/tauf
df3 = (fic3x - f3)*Tscal/tauf
df4 = (fic4x - f4)*Tscal/tauf
df5 = (fic5x - f5)*Tscal/tauf

fic1 = max(0,min(fcon,f1))
fic2 = max(0,min(fcon,f2))
fic3 = max(0,min(fcon,f3))
fic4 = max(0,min(fcon,f4))
fic5 = max(0,min(fcon,f5))

" FLASHING MODEL

fif1 =  if tps < t1 then kfl*(t1 - tps) else 0
fif2 =  if t1 < t2 then kfl*(t2 - t1) else 0
fif3 =  if t2 < t3 then kfl*(t3 - t2) else 0
fif4 =  if t3 < t4 then kfl*(t4 - t3) else 0
fif5 =  if t4 < t5 then kfl*(t5 - t4) else 0
```

APPENDIX
SIMNON code

```
" WATER FLOW OUT OF THE NODES

fiwo1 = if m1>wlim then fic1 else 0
fiwo2 = if m2>wlim then fic2 else 0
fiwo3 = if m3>wlim then fic3 else 0
fiwo4 = if m4>wlim then fic4 else 0
fiwo5 = 0

A = 2*V*eps*gamma*(D/2+L)/(D*r)
wlim = A*film*row

ms = V*eps*ros
c1 = ms*cps

"THE ENERGY EQUATIONS

d1 = hc*(fic1 - fif1)*Tscal/c1
d2 = (hc*(fic2 - fif2) + fiwo1*cpw*(t1 - t2))*Tscal/c1
d3 = (hc*(fic3 - fif3) + fiwo2*cpw*(t2 - t3))*Tscal/c1
d4 = (hc*(fic4 - fif4) + fiwo3*cpw*(t3 - t4))*Tscal/c1
d5 = (hc*(fic5 - fif5) + fiwo4*cpw*(t4 - t5))*Tscal/c1

"Parameters:

hc:         2.1E6      "[J/kgK]
kf:         100        "
drdp:       0.5        "[kg/(m3 bar)]
V:          2.355      "[m3]
Vtot:       23.55      "[m3]
film:       0.35E-3    "[m]
gamma:      0.75       "[pu]
Tscal:      3600       "[pu]
r:          0.017      "[m]
pout:       1          "[bar]
row:        1000       "[kg/m3]
cpw:        4.18E3     "[J/kgK]
ros:        2700       "[kg/m3]
cps:        800        "[J/kgK]
eps:        0.58       "[pu]
kin :       1
tauf:       20         "[s]
kfl:        0.01     "
eta:        0.28E-3     "[Pas]
lambdaw:    0.3E-3      "[W]
D:          0.0278      "[m]
L:          0.035       "[m]
rol:        1E3         "[kg/m3]
rog:        20          "[kg/m3]
dhn:        2.1E6       "[J/kg]
fcon:       0.2

END
```

APPENDIX
SIMNON code

```
CONTINUOUS SYSTEM COND2
"
"FILE: KARL2.T
"
"Description:   A mathematical model of the Karlshamn
"               experiment
"
"Author:        S.Bergman
"               P.Persson
"

STATE t6 t7 t8 t9 t0 m6 m7 m8 m9 m0
STATE f6 f7 f8 f9 f0

DER d6 d7 d8 d9 d0 dm6 dm7 dm8 dm9 dm0
DER df6 df7 df8 df9 df0

INPUT  p  fi5 fic5 t5
OUTPUT sfic2 fio sfif2

TIME t

" ts6..ts0     Node temperatures in node 6..0
" m6..m0       Water mass in node 6..0
" f6..f0       Condensing rate in nodes 1..5

" fi6..fi0     The steam flow into nodes 1..5
" fic6..fic0   The condensing rate in the nodes 1..5
" fiwo6..fiwo0 The water flow out of nodes 1..5

a1=Vtot*(1-eps)*drdp

"PRESSURE IN FILTRA

sfic2 = fic6 + fic7 + fic8 + fic9 + fic0
sfif2 = fif6 + fif7 + fif8 + fif9 + fif0

"STEAM FLOW INTO THE NODES

fi6 = max(fi5 - fic5,0)
fi7 = max(fi6 - fic6,0)
fi8 = max(fi7 - fic7,0)
fi9 = max(fi8 - fic8,0)
fi0 = max(fi9 - fic9,0)
fio = sign(p - pout)*sqrt(abs((p - pout)*p/(kout*2)))

"MASS BALANCE EQUATIONS

dm6x = (fic6 - fiwo6 - fif6)*Tscal
dm7x = (fiwo6 + fic7 - fiwo7 - fif7)*Tscal
dm8x = (fiwo7 + fic8 - fiwo8 - fif8)*Tscal
dm9x = (fiwo8 + fic9 - fiwo9 - fif9)*Tscal
dm0x = (fiwo9 + fic0 - fif0)*Tscal

dm6 = if m6<wlim then (if m6>0 then dm6x else 0) else 0
```

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SIMNON code

```
dm7 = if m7<wlim then (if m7>0 then dm7x else 0) else 0
dm8 = if m8<wlim then (if m8>0 then dm8x else 0) else 0
dm9 = if m9<wlim then (if m9>0 then dm9x else 0) else 0
dm0 = dm0x

"CONDENSATION MODEL

N = 2*V*eps/(3.14*r*D*D)
XX= 0.943*3.14*D*L
new = XX*(lambdaw^3*rol*(rol-rog)*10*dhn/(eta*L))^0.25

tt6 =  if (t5 - t6)>0 then t5 - t6 else 0
zz6 = new*tt6^0.75*N/dhn
fic6x = max(0,min(zz6,fi6))

tt7 =  if (t6 - t7)>0 then t6 - t7 else 0
zz7 = new*tt7^0.75*N/dhn
fic7x = max(0,min(zz7,fi7))

tt8 =  if (t7 - t8)>0 then t7 - t8 else 0
zz8 = new*tt8^0.75*N/dhn
fic8x = max(0,min(zz8,fi8))

tt9 =  if (t8 - t9)>0 then t8 - t9 else 0
zz9 = new*tt9^0.75*N/dhn
fic9x = max(0,min(zz9,fi9))

tt0 = if (t9 - t0)>0 then t9 - t0 else 0
zz0 = new*tt0^0.75*N/dhn
fic0x = max(0,min(zz0,fi0))

df6 = (fic6x - f6)*Tscal/tauf
df7 = (fic7x - f7)*Tscal/tauf
df8 = (fic8x - f8)*Tscal/tauf
df9 = (fic9x - f9)*Tscal/tauf
df0 = (fic0x - f0)*Tscal/tauf

fic6 = max(0,min(f6,fcon))
fic7 = max(0,min(f7,fcon))
fic8 = max(0,min(f8,fcon))
fic9 = max(0,min(f9,fcon))
fic0 = max(0,min(f0,fcon))

"FLASHING MODEL

fif6 = if t5 < t6 then kfl*(t6 - t5) else 0
fif7 = if t6 < t7 then kfl*(t7 - t6) else 0
fif8 = if t7 < t8 then kfl*(t8 - t7) else 0
fif9 = if t8 < t9 then kfl*(t9 - t8) else 0
fif0 = if t9 < t0 then kfl*(t0 - t9) else 0

" THE FLOW OUT OF THE NODES

fiwo6 = if m6>wlim then fic6 else 0
fiwo7 = if m7>wlim then fic7 else 0
```

APPENDIX
SIMNON code

```
fiwo8 = if m8>wlim then fic8 else 0
fiwo9 = if m9>wlim then fic9 else 0
fiwo0 = 0

A = 2*V*eps*gamma*(D/2+L)/(D*r)
wlim = A*film*row

ms = V*eps*ros
c1 = ms*cps

"THE ENERGY EQUATIONS

d6 = hc*(fic6 - fif6)*Tscal/c1
d7 = (hc*(fic7 - fif7) + fiwo6*cpw*(t6 - t7))*Tscal/c1
d8 = (hc*(fic8 - fif8) + fiwo7*cpw*(t7 - t8))*Tscal/c1
d9 = (hc*(fic9 - fif9) + fiwo8*cpw*(t8 - t9))*Tscal/c1
d0 = (hc*(fic0 - fif0) + fiwo9*cpw*(t9 - t0))*Tscal/c1

"Parameters:

hc:         2.1E6      "[J/kgK]
kf:         100        "
drdp:       0.5        "[kg/(m3 bar)]
V:          2.355      "[m3]
Vtot:       23.55      "[m3]
film:       0.35E-3    "[m]
gamma:      0.75       "[pu]
Tscal:      3600       "[pu]
r:          0.017      "[m]
pout:       1          "[bar]
row:        1000       "[kg/m3]
cpw:        4.18E3     "[J/kgK]
ros:        2700       "[kg/m3]
cps:        800        "[J/kgK]
eps:        0.58       "[pu]
tps:        150        "[deg C]
kout:       4          "
tauf:       20         "[s]
kfl:        0.01

eta:        0.28E-3    "[Pas]
lambdaw:    0.3E-3     "[W]
D:          0.0278     "[m]
L:          0.035      "[m]
rol:        1E3        "[kg/m3]
rog:        20         "[kg/m3]
dhn:        2.1E6      "[J/kg]
fcon:       0.2

END
```

APPENDIX
SIMNON code

```
CONTINUOUS SYSTEM PGEN

"File: PGEN.T

"Author: S. Bergman
"        P. Persson


TIME t

OUTPUT p tsat

p2 = p0*exp(-t/t0)+n
p1 = a + b*t
p = max(p1,p2)

"SATURATION TEMPERATURE

n1 = (d12*p + d11)*p + d10
n2 = ((d23*p + d22)*p + d21)*p + d20
n3 = ((((d35*p + d34)*p + d33)*p + d32)*p + d31)*p + d30
tsat = if p<0.074 then n1 else if p<1 then n2 else n3

"Parameters:

p0:         2.8
n :         1
t0:.        3
a :         6.5
b :        -70
d10:        3.8
d11:        799.8
d12:        -4192
d20:        23.6589
d21:        246.1716
d22:        -356.2139
d23:        185.1883
d35:        0.0022
d34:        -0.0862
d33:        1.2729
d32:        -9.2226
d31:        40.5605
d30:        67.1414

END
```

APPENDIX
SIMNON code

```
CONNECTING SYSTEM CONKARL

"File: CONDYN.T

"Author:  S. Bergman
"         P. Persson

pst[cond1]=p[pgen]
sfic2[cond1]=sfic2[cond2]
fio[cond1]=fio[cond2]
tps[cond1]=tsat[pgen]
sfif2[cond1]=sfif2[cond2]

p[cond2]=p[cond1]
fi5[cond2]=fi5[cond1]
fic5[cond2]=fic5[cond1]
t5[cond2]=t5[cond1]

END
```

APPENDIX
SIMNON macro

```
MACRO MACCOND

let fname.ifile=mava
let n.ifile=2

syst cond ifile react ps concond

par dt[ifile]:0.01

init p[cond]: 1.0
init bl[cond]: 0.0
init cl[cond]: 0.0

init ts1[cond]: 20.0
init ts2[cond]: 20.0
init ts3[cond]: 20.0
init ts4[cond]: 20.0

init m1[cond]: 100.0
init m2[cond]: 100.0
init m3[cond]: 100.0
init m4[cond]: 100.0

init f1[cond]: 0
init f2[cond]: 0
init f3[cond]: 0
init f4[cond]: 0

init E[react]: 7.22E10
init Wr[react]: 90
init pr[react]: 70

init ps[psc]: 1.0
init mps[psc]: 1940000.0
init Tps[psc]: 30.0
init mq[psc]:  0.0

algor rk

store pq Vc
store ps[psc] fio prs qcs qbs ts[psc] -add
store p[cond] Tps[psc] mps -add
store fi1[cond] fi2 fi3 fi4 fic1 fic2 fic3 fic4 -add
store fif1 fif2 fif3 fif4 -add
store ts1 ts2 ts3 ts4 -add
store m1 m2 m3 m4 -add
store sfic sfif -add
store Qprod[psc] -add
store pr[react] qmava[react] -add
store q323 -add
store fif1 fif2 fif3 fif4 -add

par Qc32:0  "No heat exchanger active

END
```

APPENDIX
SIMNON macro

```
MACRO MACDYN

syst karl1 karl2 pgen condyn
algor rk
init x:  0

init m1[cond1]: 1
init m2[cond1]: 1
init m3[cond1]: 1
init m4[cond1]: 1
init m5[cond1]: 1

init m6[cond2]: 1
init m7[cond2]: 1
init m8[cond2]: 1
init m9[cond2]: 1
init m0[cond2]: 1

init t1[cond1]: 20
init t2[cond1]: 20
init t3[cond1]: 20
init t4[cond1]: 20
init t5[cond1]: 20

init t6[cond2]: 20
init t7[cond2]: 20
init t8[cond2]: 20
init t9[cond2]: 20
init t0[cond2]: 20

init f1[cond1]: 0
init f2[cond1]: 0
init f3[cond1]: 0
init f4[cond1]: 0
init f5[cond1]: 0

init f6[cond2]: 0
init f7[cond2]: 0
init f8[cond2]: 0
init f9[cond2]: 0
init f0[cond2]: 0

init p[cond1]: 1

store m1 m2 m3 m4 m5 m6 m7 m8 m9 m0
store t1 t2 t3 t4 t5[cond1] t6 t7 t8 t9 t0[cond2] -add
store p[cond1] p[pgen] x[cond1] -add
store fi1[cond1] fi2 fi3 fi4 fi5[cond1]-add
store fi6 fi7 fi8 fi9 fi0 fio[cond2] -add
store fic1 fic2 fic3 fic4 fic5[cond1]-add
store fic6 fic7 fic8 fic9 fic0 -add
store fif1 fif2 fif3 fif4 fif5 -add

END
```