Additional Information Concerning the Physical Behaviour of the Steam Boiler

In this note, we *propose* some additional information about a possible model of the boiler system. Such information can be taken into account in the construction of your own model. We shall use the notational conventions described in section 2.6. of the specification that has already been distributed to you.

Besides the *raw* measures q, p, and v, we shall consider the following quantities that are called the *adjusted* values

qa1, qa2 minimal and maximal *adjusted* quantity of water

pa1,pa2 minimal and maximal *adjusted* throughput of the pumps

va1,va2 minimal and maximal *adjusted* quantity of exiting steam

Such adjusted quantities are defined to be either the *raw* values effectively delivered in the messages or the *calculated* values estimated from previous cycle. The raw values are chosen in case the corresponding equipment is considered to be not broken. Otherwise, the calculated quantities are chosen.

The calculated quantities are denoted as follows:

qc1, qc2 minimal and maximal calculated quantity of water

pc1,pc2 minimal and maximal calculated throughput of the pumps

vc1, vc2 minimal and maximal calculated quantity of exiting steam

We have thus:

qa1 = qc1, if the water level equipment is considered broken, and

qa1 = q otherwise.

qa2 = qc2, if the water level equipment is considered broken, and

qa2 = q otherwise.

Similar definitions hold for the other quantities.

The calculated quantities can be determined from the adjusted quantities as follows:

$qc1 = qa1 - va2\ \Delta t - 1/2\ \ U_1\ \Delta t^2 + pa1$

$qc2 = qa2 - va1\ \Delta t + 1/2\ \ U_2\ \Delta t^2 + pa2$

$rc1 = ra1 - U_2\ \Delta t$

$rc2 = ra2 + U_1\ \Delta t$

$pc1 = \Sigma_{i \in 1..4}\ pc_{1,i}$

$pc2 = \Sigma_{i \in 1..4}\ pc_{2,i}$

where Δt is the cycle time and where $pc_{1,i}$ and $pc_{2,i}$ are the minimal and maximal throughputs of each individual pump/monitor. Such quantities are defined as follows:

$pc_{1,i} = 0$ if C_i holds, and

$pc_{1,i} = P$ otherwise.

$pc_{2,i} = P$ if D_i holds, and

$pc_{2,i} = 0$ otherwise.

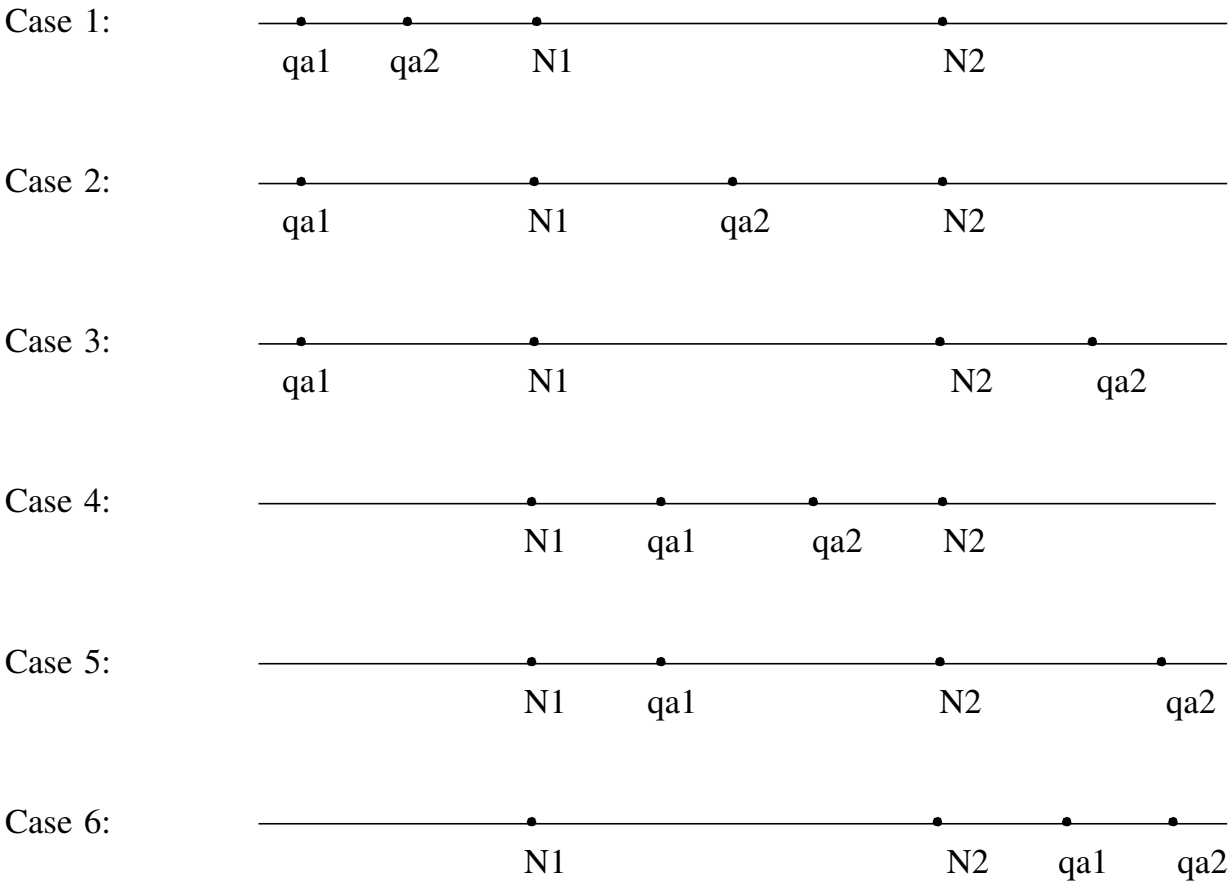
When the condition C_i holds, we *consider* that the water is not flowing through the i-th pump. This is the case when the i-th pump/monitor is broken (since, in that case, we have *no information* and thus we estimate the worst *minimal* throughput to be 0). This is also the case when either the order to close the pump has just been given or when we know that the pump was already closed.

When the condition D_i holds, we *consider* that the water is flowing through the i-th pump. This is the case when the i-th pump/monitor is broken (since, in that case, we have *no*

information and thus we estimate the worst *maximal* throughput to be P). This is also the case when either the order to open the pump has just been given or when we know that the pump was already open. Clearly the previous conditions C_i and D_i could be made more elaborate.

Note that an equipment (that is not already considered broken) becomes broken when the corresponding raw quantity is not a member of the interval of quantities *calculated* at the previous cycle.

To determine whether the water level is too low (opening the pumps) or too high (closing the pumps), we have to use now the interval (qa1, qa2). There are thus 6 cases to consider according to the following diagrams:



We might consider the following decisions:

Case 1	opening pumps
Case 2	
Case 3	?
Case 4	do nothing
Case 5	closing pumps
Case 6	

Case 3 poses a problem. We might decide to do nothing, as in case 4.
The decision concerning shutdown is simpler. We might decide to shut the system down when at least one of the following condition holds

$qa1 \leq M1$
$qa2 \geq M2$
$qc1 \leq M1$
$qc2 \geq M2$

Here qc1 and qc2 are the calculated values for *next* cycle.