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# DM--RA-TBSIDDA---Clarification of basis for Cooling Water temperatures.docx

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# 1. BACKGROUND

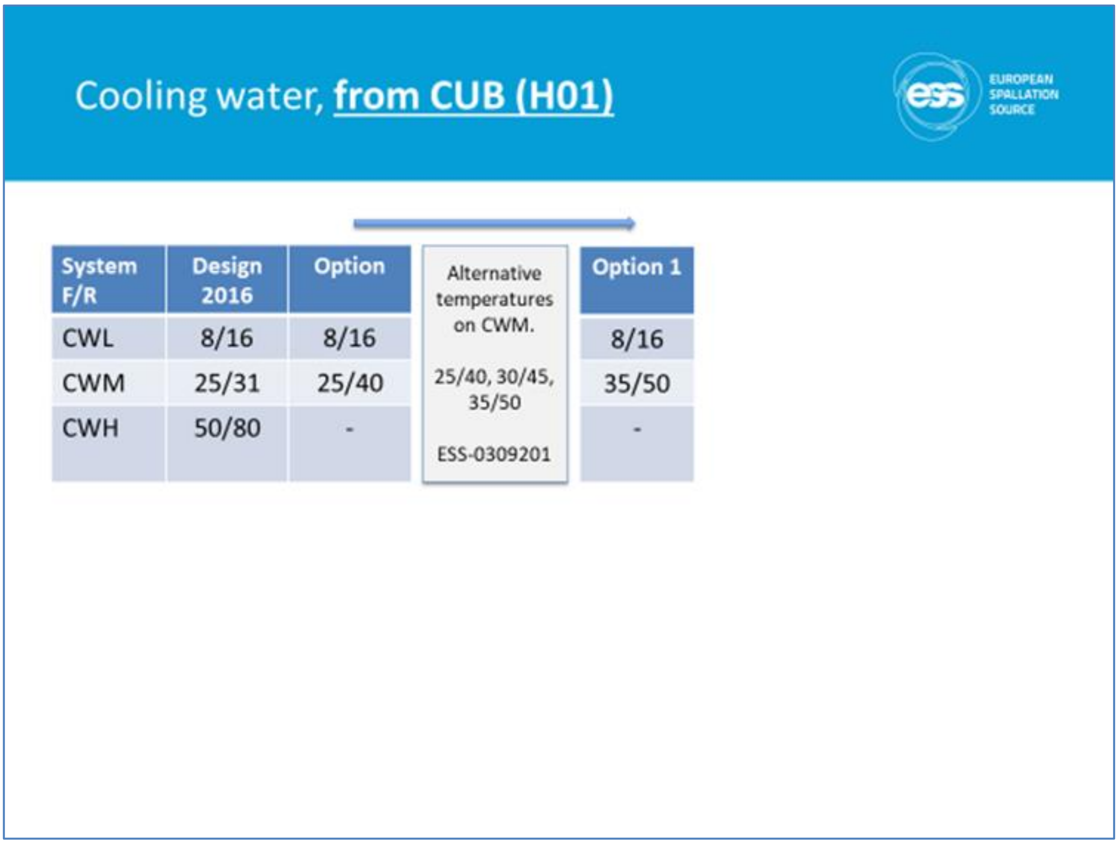
The ESS water cooling system accomplishes two goals. The primary goal is to remove waste heat and provide adequate cooling and temperature control for all systems to assure safe and efficient facility operation. The second goal is to recycle as much of the waste heat as practicable and provide it to external customers. The Central Processing System (CPS) installed in the Central Utility Building (CUB) will contain all the equipment necessary for supplying cooling water on site and transferring the heat to the external district heating system(s).

This document has been added to summarize and describe temperature levels on cooling water discussed historically within ESS. The purpose of the document is to rectify uncertainties that have occurred and to provide basis for design.

The document is based on slides earlier presented in a forum with Mr Roland Garoby, Mr Ferenc Mezei, Mr Lennart Stenman and Roy Ericsson.

# 2. FROM 2016 AND FORWARD

In the design from 2016 it was stated different temperatures on CWL, CWM and CWH from CPS system in CUB. As concerns arose that temperatures could be too high on the Klystron collector's, various alternative temperatures were evaluated during the procurement phase, according to slide below. The Option 1 is further described in the document ESS-0309201.




| System F/R | Design 2016 | Option | Option 1 |
|---|---|---|---|
| CWL | 8/16 | 8/16 | 8/16 |
| CWM | 25/31 | 25/40 | 35/50 |
| CWH | 50/80 | - | - |

# 3. FACTS ON TEMPERATURES

The procurement phase was followed by a period of optimization of the CWM and CWH circuits taking into account:

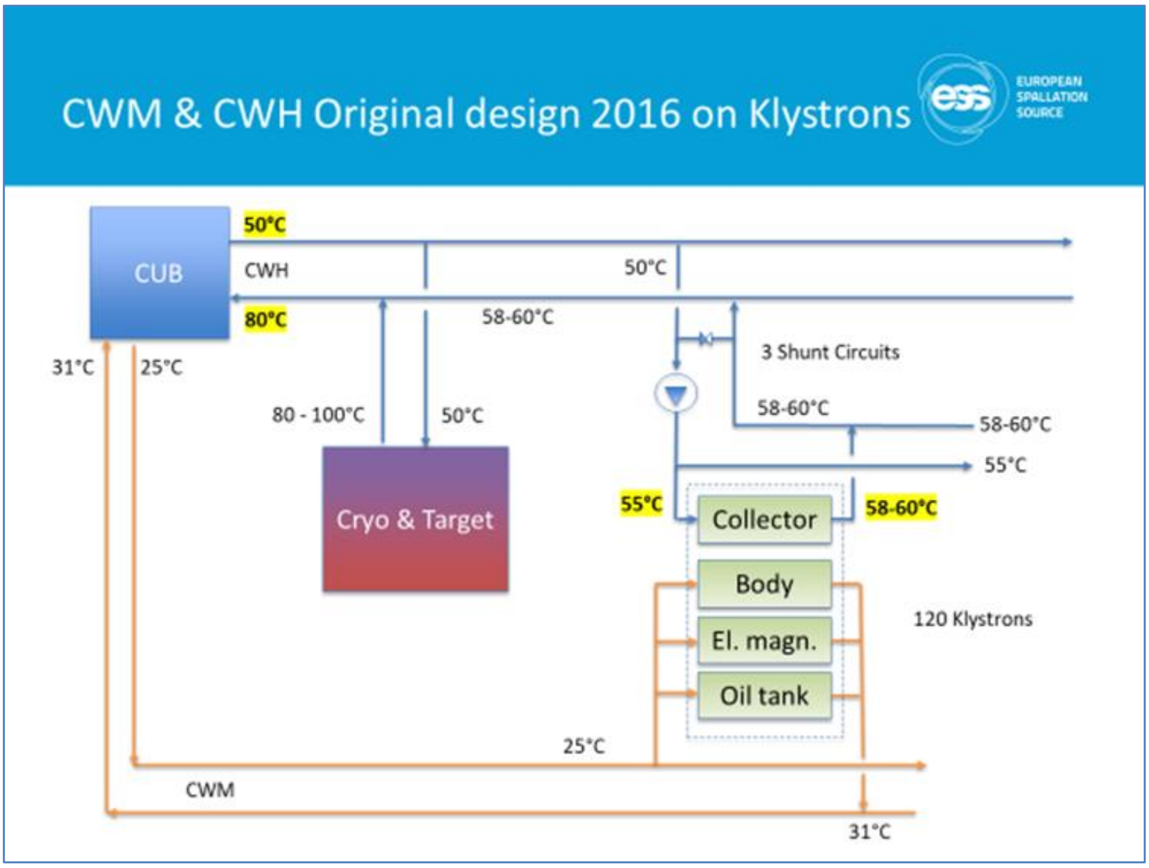
- The 3 individual shunt circuits supplying the Klystrons with a very high flow and low Δt, about 5°C.
- The new fact, discovered in cooperation with Kraftringen, that the return temperature from Kraftringen is seriously higher than the expected maximum 45°C, which was the basis for the earlier design. This fact has big influence on the amount of cooling that can be direct cooled towards the DH return.

These aspects are further described in the subheadings below.

## 3.1. Design 2016

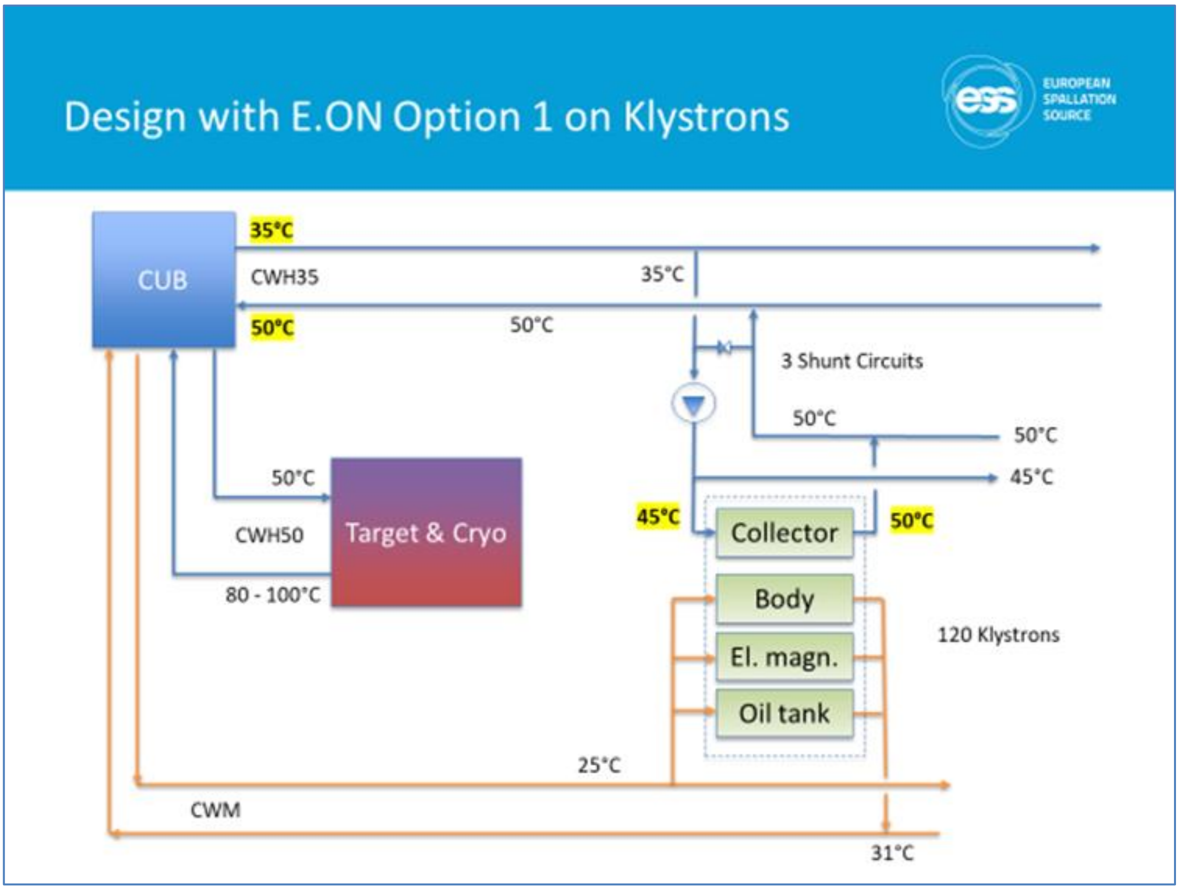
The design from 2016 on the CWH system stated, according to the sketch below:

- 50/80°C from CPS (CUB).
- 3 separate shunt circuits in the Klystron Gallery providing high flow and low Δt (55/60°C) over the Klystron Collectors.



## 3.2. The Option 1 from E.ON

Even if the outgoing temperature on CWH was reduced from 50°C to 35°C in this Option 1, the existing shunt circuits meant that difference over the Klystrons was not that large, since we wanted 50°C on the secondary side of the Klystrons, see sketch below.




During the discussions on Option 1 it was decided to split the CWH system into two. This was found appropriate according to the implementation phase as the pipes in the ground outside CUB were just being built. It also opened a door for different future possibilities, the split of CWH resulted in:

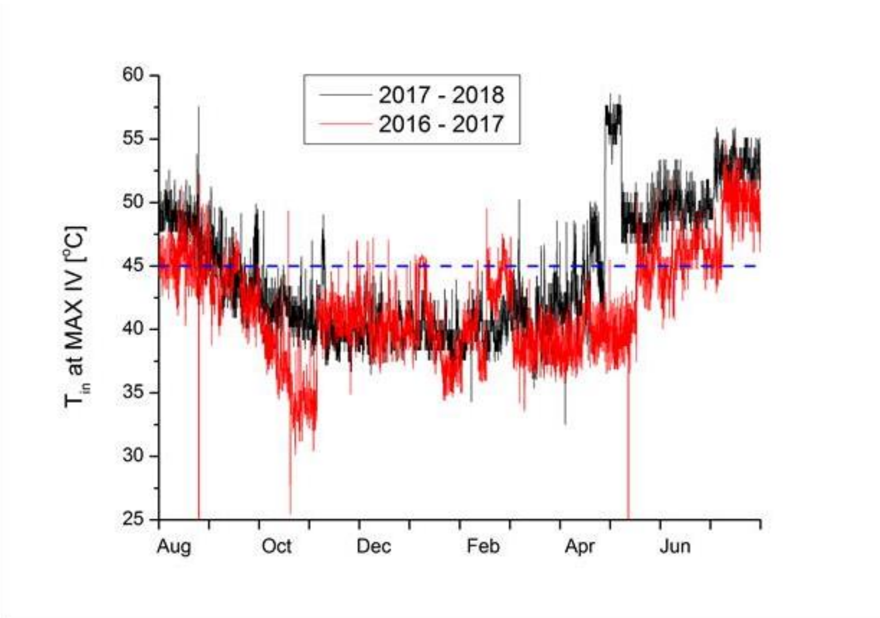
CWH 35 - 2 pair of pipes providing 35/50 for the Klystron Gallery, 6,0 MW.

CWH 50 – 2 pair of pipes providing 50/80 for Target and Cryo, 4,8 MW.

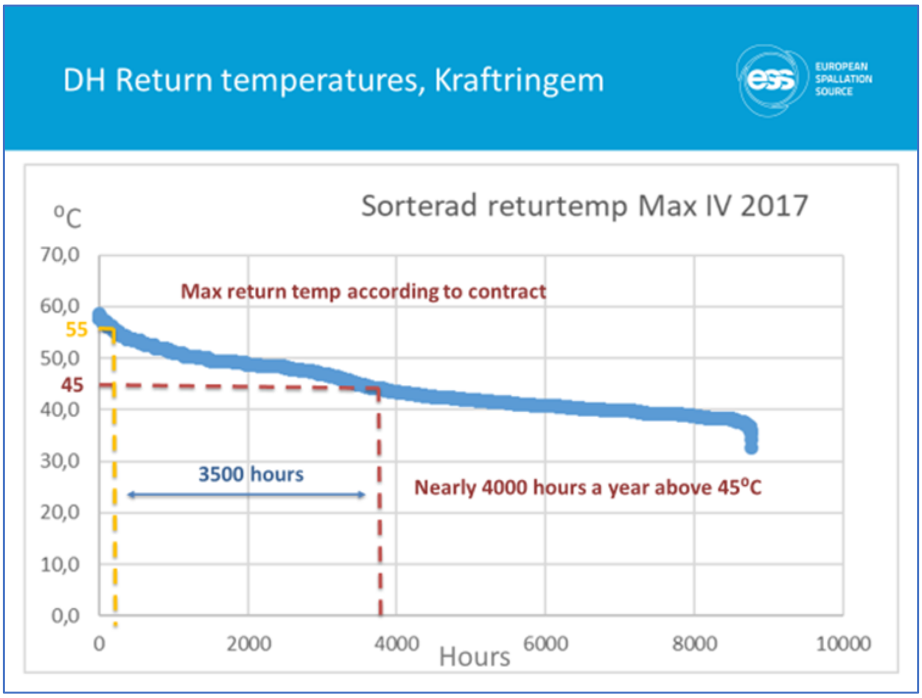
Preparations and rebuilding the system in the ground for this have already been completed.

## 3.3. DH return temperatures exceeding 45°C

The DH return temperatures was analyzed (close to Max IV) together with E.ON and Kraftringen, resulting in the curves according to diagram below:




Sorted figures, 2017-2018 from highest to lowest, according to diagram below shows:

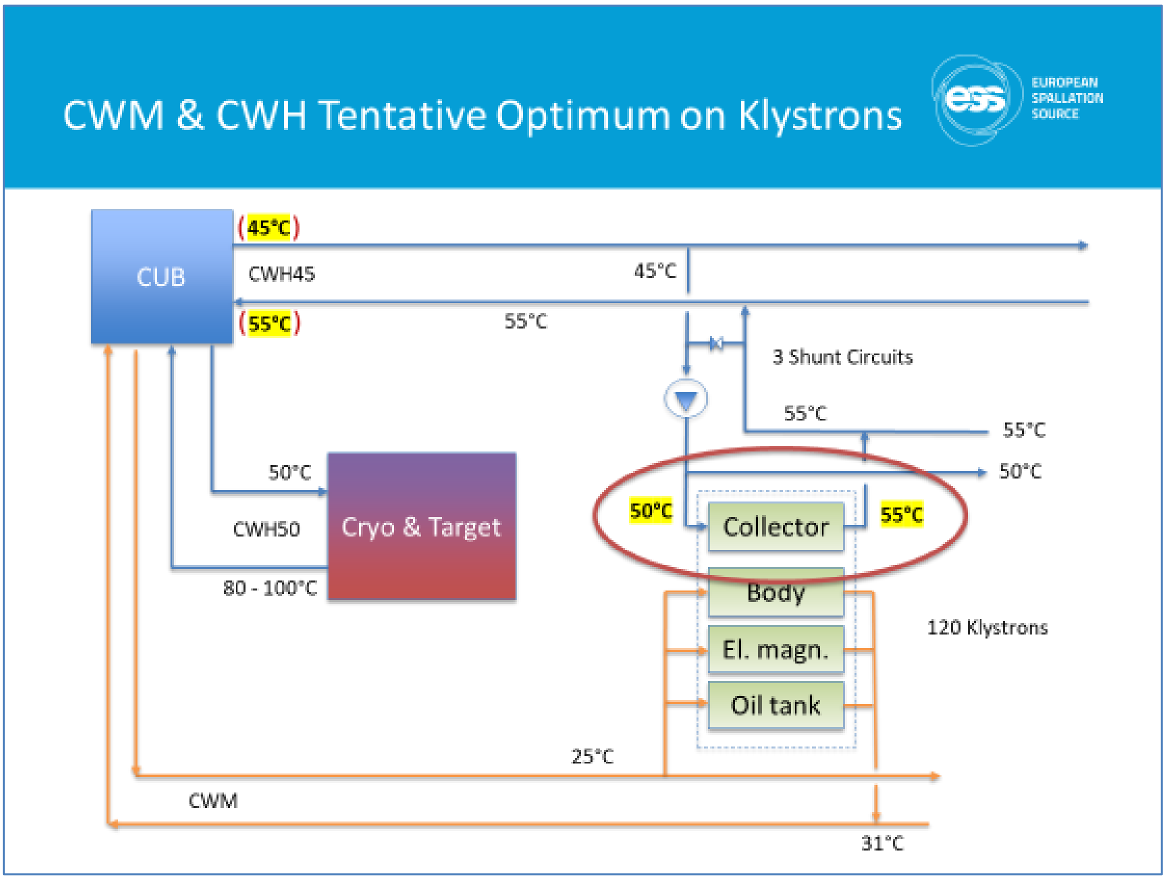



1. Nearly 4000 hours a year the temperature can be expected to exceed 45°C which was the original design temperature.
2. The return temperature can be expected to exceed 50°C for 1500 hours, and above 62°C only a very few hours yearly.

# 4. TENTATIVE OPTIMUM

Further optimization resulted in a Tentative Optimum for the CWH systems to the Klystrons, also taking into account the higher temperatures on DH return from Kraftringen.

The Tentative Optimum stated 55°C as a maximum outlet from the Klystrons. Meaning with 5°C Δt we can allow up to 50°C to the Klystrons, according to sketch below:




The header pipe leaving from CUB towards the Klystron Gallery has the dimension DN 500 and before the Klystron Gallery it is reduced to DN 450. The maximum velocity in the 10°C Δt case is 0,9 m/s.

| Cooling demand MW (3 MW BoT) | Header DN, mm | Δt °C | Velocity m/s |
|---|---|---|---|
| 6,0 | 450 | 10 | 0,9 |

The recommended maximum velocity in a pipe dimension of DN 450 is 3 m/s.

This means that even with only 5°C Δt out from CUB can provide the full cooling demand for the Klystrons at 3 MW Beam on Target (BoT), see table below:

| Cooling demand MW (3 MW BoT) | Header DN, mm | Δt °C | Velocity m/s |
|---|---|---|---|
| 6,0 | 450 | 5 | 1,8 |

For the future case, 5 MW BoT, the cooling demand for the Klystron Gallery is calculated to maximum 8,4 MW. Either we can supply at a Δt 10°C or allow the velocity to increase up to 2,5 m/s, according to table below:

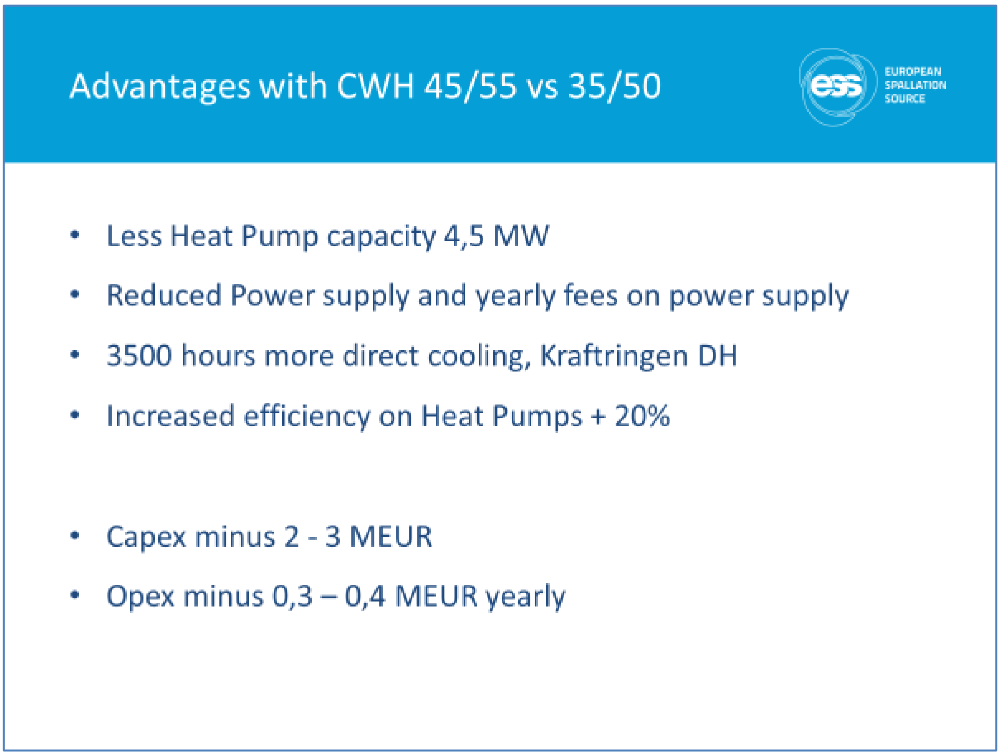
| Cooling demand MW (5 MW BoT) | Header DN, mm | Δt °C | Velocity m/s |
|---|---|---|---|
| 8,4 | 450 | 10 | 1,3 |
| 8,4 | 450 | 5 | 2,5 |

Concluding that the capacity in the CWH systems for the Klystron Gallery is satisfying, even for future expansions.

### 4.1. Advantages with the Tentative Optimum

The Tentative Optimum with a return temperature of 55°C from Klystrons means that we can transfer surplus heat with heat exchangers to the Kraftringen DH return as long as this DH return is lower, at least 7000 hours a year. This saves both capacity and energy in heat pumps.

The benefits of the Tentative Optimum (45/55) compared to the Option 1 (35/50) are therefore convincing as summarized in the picture below.



# 5. PROPOSED DECISION AND PLAN OF ACTION

With the goal to limit the output temperature from Klystrons to a maximum of 55 °C, the CWH system is proposed to be divided into two circuits where one supplies Klystrons and the other supplies Cryo and Target. Preparations and rebuilding the system in the ground for this have already been completed.

The CWH circuit that supplies the 3 Klystron shunt circuits is suggested to be controlled to never exceed 55°C on the outgoing circuit from the Klystrons. This also means that the supply temperature from CPS can vary theoretically up to 50°C.

The circuit supplying Cryo and Target is generally suggested to be unchanged but to allow the outgoing temperature to be adapted to the other CWH circuit. Supplying 45°C instead of 50°C will not have any negative impact on Cryo and Target.

It is proposed that the solution for the technical design of these two circuits shall be transferred to E.ON in their delivery of the CPS.

# 6. REFERENCES


[1] ESS-doc-274 (ISBN 978-91-980173- 2-8), ESS Technical Design Report (Table 7.7 - p.520).
[2] ESS-0068371, ESS Central Process Systems Technical Requirements.
[3] ESS-0309201, CPS cooling temperature options.
[4] ESS-0337914, Basis for decision for Cooling Water Temperature for Cooling Water Temperature.
[5] ESS-0482607, DM—AV-TBSIDD----Specifications Central Process System 3MW Beam on Target.


# DOCUMENT REVISION HISTORY

| Revision | Reason for and description of change | Author | Date |
|---|---|---|---|
| 1 | First issue | Roy Ericsson | 2019-01- |