Calorimetric power calculation

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HELMHOLTZ GEMEINSCHAFT

DESY

Introduction

Static mode:

$$\langle P_{gun} \rangle = C_{P,V} \cdot J \cdot \Delta T$$

where:

$C_{P,V} = 4.19$ – isobaric volumetric heat capacity of the water (at T ≈ 75 deg C), $\frac{J}{cm^3 \cdot K}$

J – water flux, $\frac{cm^3}{s}$

ΔT – Outcoming to incoming temperature difference, K

Then:

$$\left[\langle P_{gun} \rangle\right] = \frac{J}{cm^3 \cdot K} \cdot \frac{cm^3}{s} \cdot K = \frac{J}{s} \equiv W$$

Available DOOCS data

J_{DOOCS} – water flux, $\frac{m^3}{h}$

$T_{in,DOOCS}$ – input water temperature, deg C

$T_{out,DOOCS}$ – output water temperature, deg C

Lets rewrite:

$$\langle P_{gun} \rangle = C_{P,V} \cdot J \cdot \Delta T$$

to:

$$\langle P_{gun} \rangle = A \cdot J_{DOOCS} \cdot \Delta T_{DOOCS}$$

where:

$$A = 4.19 \cdot \frac{J}{10^{-6} \cdot m^3 \cdot K} \cdot \frac{m^3}{3600 \cdot s} \cdot K = 1163.8(8) \cdot W$$

Calculate peak power:

$$P_{gun,peak} = \frac{\langle P_{gun} \rangle}{f \cdot L_{RF}} \cdot 10^{-6}, MW$$

where:

f – repetition rate, Hz

L_{RF} – RF pulse length, s

DOOCS calculation

Lets rewrite:

$$P_{gun,peak} = \frac{\langle P_{gun} \rangle}{f \cdot L_{RF}} \cdot 10^{-6}, MW$$

to:

$$P_{gun,peak} = \frac{\langle P_{gun} \rangle}{f_{DOOCS,[Hz]} \cdot 10^{-6} L_{RF,DOOCS[\mu s]}} \cdot 10^{-6}, MW = \frac{\langle P_{gun} \rangle}{f_{DOOCS,[Hz]} \cdot 10^{-6} L_{RF,DOOCS[\mu s]}}, MW$$

Finally, substituting $\langle P_{gun} \rangle$, we have:

$$\boldsymbol{P_{gun,peak} = \frac{A \cdot J_{DOOCS,[m^3/h]} \cdot \Delta T_{DOOCS,K}}{f_{DOOCS,[Hz]} \cdot L_{RF,DOOCS[\mu s]}}, MW}$$

This formula is implemented in WCS DOOCS server, calculated data is available at the following location:

“PITZ.WATER/WCS/GUN/ABSORBED_POWER”, calculated value is displayed in PITZ GUI under “PITZ => water/temperature => gun”.

Constant A is specified under:
“PITZ.WATER/WCS/GUN/HEAT_CAPACITY”

Errors estimation

Error sources:
- Precision of flux meter
- Precision of temperature sensors
- Rise and decay times at RF pulse

Flux meter: 0.5% relative.

Temperature sensors:
- **from electronics: 0.02 deg C absolute for each sensor.**
- **from sensor itself (according to producer): 0.1 deg C**

Rise and decay times: depends on RF pulse configuration and has to be estimated for certain conditions.

Error estimation example

Conditions:

- 8.35 MW in the gun according to 2x5MW couplers
- 40/200\15 us RF pulse
- 9.2 MW in the gun according to calorimetric calculation

Errors:

- from flux meter: +/- 0.05 MW
- from RF pulse: + 0.3 MW
- from temperature sensors: +/- 0.7 MW

Therefore:
P(water) = 9.2 +/- 0.7 - 0.3 MW =>

9.6 MW
8.2 MW

Quite big uncertainty, mainly due to temperature sensors

Summary

- Calorimetric power calculation looks reliable.
- For longer RF pulse durations results will be more reliable as there is less influence of rise/decay times of the RF pulse and also less influence of precision of temperature sensors.