The NCG sensor
and the standard
EN285:2015

Steam quality in terms of NCG mass fraction

The NCG fraction in the sterilizer chamber can be defined unambiguously in terms of a mass fraction. This is a substantial improvement with respect to the standards, where the NCG fraction in the steam supply is defined in terms of ml NCGs in 100 ml condensate. One should note that at the time these standards were developed no instruments were available to measure the actual mass fraction.

The definition in the standards has the drawback that it cannot be related one-to-one to the steam fraction in the sterilizer chamber, which is the actual quantity of interest. This will be demonstrated by the calculations below.

We start with the standards, which define a maximum of 3.5 ml NCGs in 100 ml condensate. We will assume that the main contribution to the NCGs results from air. The measurement system described in the standards may operate at temperatures ranging from 20 °C to 80 °C and at ambient pressures ranging roughly from 97.1 to 104.7 kPa (lowest and highest values in The Netherlands during the past decade).

The density of air depends on both temperature and pressure, and therefore the mass of the 3.5 ml NCGs is not always the same.

The minimum mass occurs at a temperature of 80 °C and an ambient pressure of 97.1 kPa.
The air density at these conditions (at an RH of 100 %, because the air is in direct contact with the condensate) equals 0.7812 kg/m^3 = 0.7812 mg/ml.
The mass of 3.5 ml air at these conditions equals 2.734 mg.

The maximum mass occurs at a temperature of 20 °C and an ambient pressure of 104.7 kPa.
The air density at these conditions (at an RH of 100 %, because the air is in direct contact with the condensate) equals 1.2337 kg/m^3 = 1.2337 mg/ml.
The mass of 3.5 ml air at these conditions equals 4.318 mg.

The density of water has a negligible pressure dependence, so only the temperature is considered.
At 80 °C the water density equals 972 kg/m^3 = 972 mg/ml.
The mass of 100 ml water at that temperature equals 97.2 gram.
At 20 °C the water density equals 998 kg/m^3 = 998 mg/ml.
The mass of 100 ml water at that temperature equals 99.8 gram.

For 3.5 ml NCGs in 100 ml condensate, the ratio of the masses of air and water may range between $2.734\times10^{-3}/972 = 2.81\times10^{-5}$ and $4.318\times10^{-3}/998 = 4.32\times10^{-5}$, depending on the environmental conditions.

If the actual NCG mass fraction is smaller than 2.81×10^{-5}, the steam quality is certainly better than the limit defined in the standards (GREEN).
If the actual NCG mass fraction is larger than 4.32×10^{-5}, the steam quality is certainly worse than the limit defined in the standards (RED).
In the region of NCG mass fractions between 2.81×10^{-5} and 4.32×10^{-5}, the steam quality is equal to the limit in the standards within the inherent uncertainty of the measurement procedure described in these standards (ORANGE).

SolidToo

Calibration of the NCG sensor

One of the output signals of the NCG sensor is a temperature difference reflecting the heat extracted from the measurement section of the NCG sensor, denoted by dTsink. The lower the amount of NCGs, the higher the steam quality and the value of dTsink.

The sensor is calibrated by connecting it to a chamber with a mixture of steam and NCGs at a temperature of 134 °C. The mass fraction of NCGs can be adjusted by adding known amounts of (homogeneously distributed) air to the chamber. The result of such a calibration is depicted schematically in Figure 1 below.

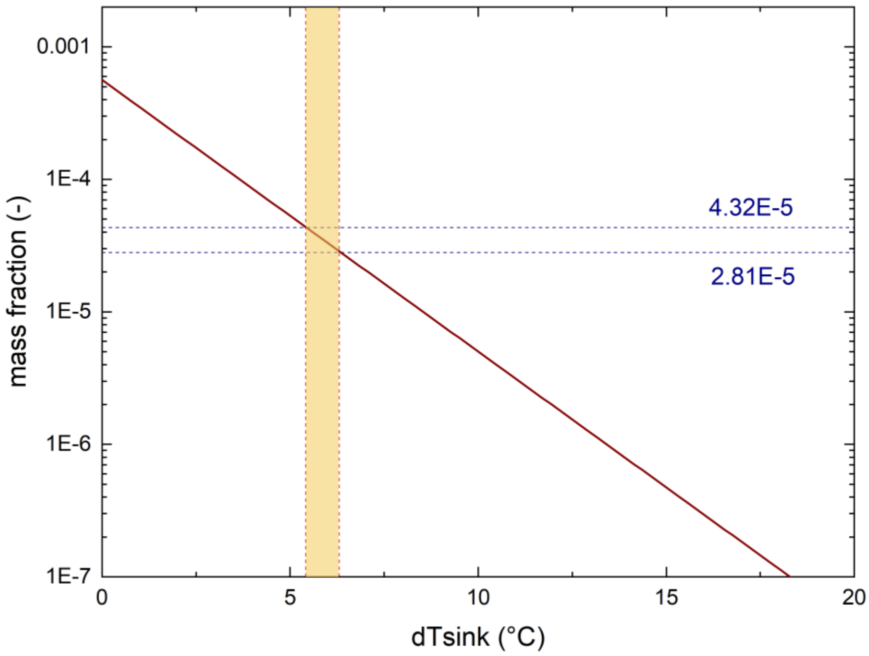

Figure 1: Typical calibration of dTsink against the mass fraction of NCGs.

The solid red line reflects the calibration. The horizontal dashed lines denote the limits of the NCG mass fraction corresponding to 3.5 ml air in 100 ml condensate. Using the sensor calibration the region between these mass fraction limits can be expressed in a region of dTsink, which is illustrated by the vertical orange bar. At values of dTsink higher than this 'orange' region, the steam quality is certainly better than the limit defined in the standards. At values of dTsink lower than this 'orange' region, the steam quality is certainly worse than the limit defined in the standards.

Plots and results of the measurements

In the plots / protocols of the measured data the value of dTsink is plotted along the vertical axis, multiplied by a scaling factor ranging from 5 to 7 (only for clarity). The orange region reflecting the inherent uncertainly in the standard is now denoted by a horizontal bar. This is illustrated in Figure 2 below. In this plot also the uncertainty in the measured value of dTsink has been included. This uncertainty typically amounts to 0.2 °C, which slightly increases the span of the 'orange' region.

Figures 2 to 4 illustrate results obtained for different sterilizers and different NCG sensors, each with their specific calibration. Moreover, one of these examples refers to a 121 °C process, where the dTsink values are about 10 % lower than those of a 134 °C process because of the lower temperature of the steam and condensate. This is taken into account in the processing of the experimental data.

These figures show the temperature in the sterilizer chamber (blue curve), the pressure (red curve) and the values of dTsink (green curve). The conversion of the measured values of dTsink to NCG fractions now proceeds as follows:

- For values of dTsink above the orange region, the criteria defined in the standards are certainly met. The possible experimental error in dTsink is subtracted from the measured value (worst case), before converting the value to an NCG fraction (expressed as percent air to condensate).
- For values of dTsink below the orange region, the criteria defined in the standards are certainly not met. The possible experimental error in dTsink is added to the measured value (best case), before converting the value to an NCG fraction (expressed as percent air to condensate).
- For values of dTsink within the orange region, the criteria defined in the standards are met within the inherent uncertainties and experimental inaccuracies.

The upper and lower boundary of the orange region correspond to the limiting NCG mass fractions of 2.81×10^{-5} (worst case) and 4.32×10^{-5} (best case) which are obtained by converting the percentage air to condensate defined in the standards to an actual mass fraction.

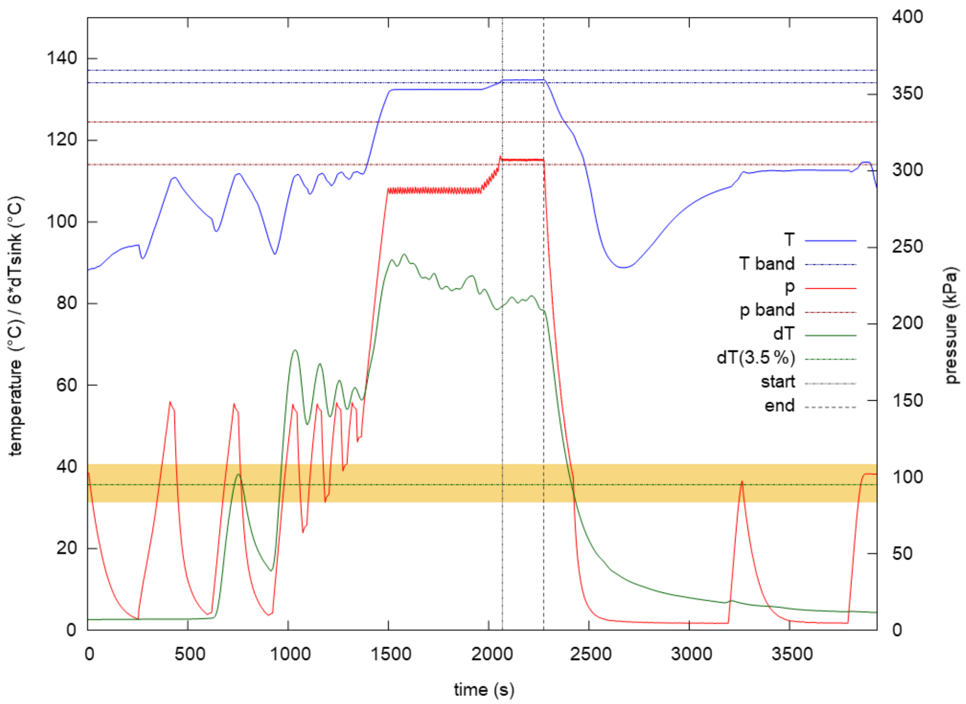

*Figure 2: Plot of the data measured by the NCG sensor for a **PASS** process.*
In the holding phase: NCG = 0.12 % (min) - 0.16 % (max).

SolidToo

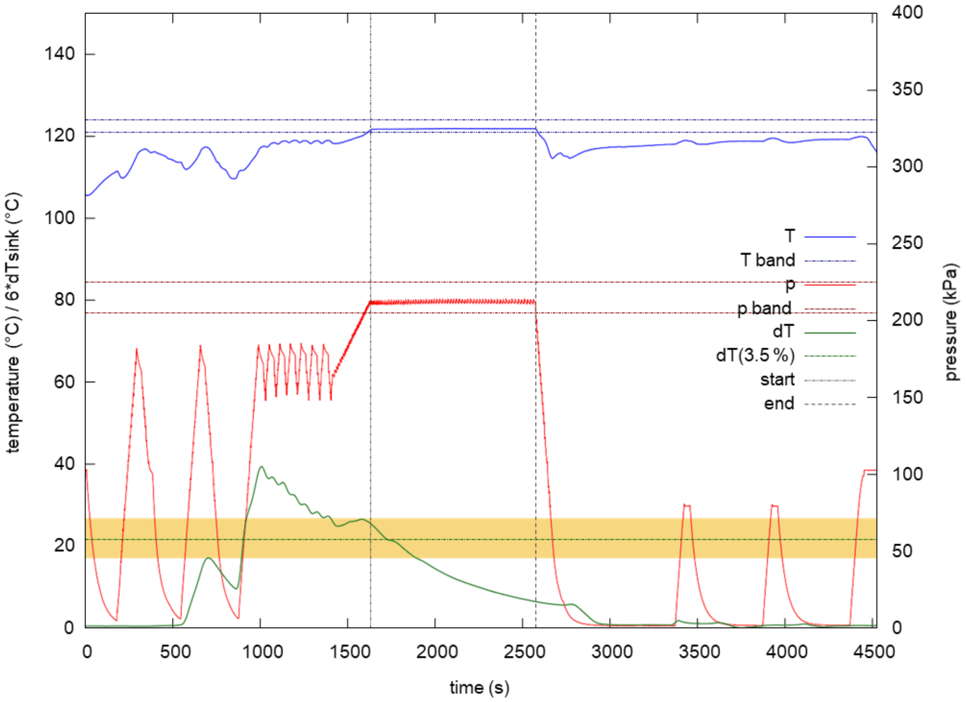

Figure 3: Plot of the data measured by the NCG sensor for a ***FAIL*** *process.*
In the holding phase NCG = 3.0 % (min) - 11.6 % (max).

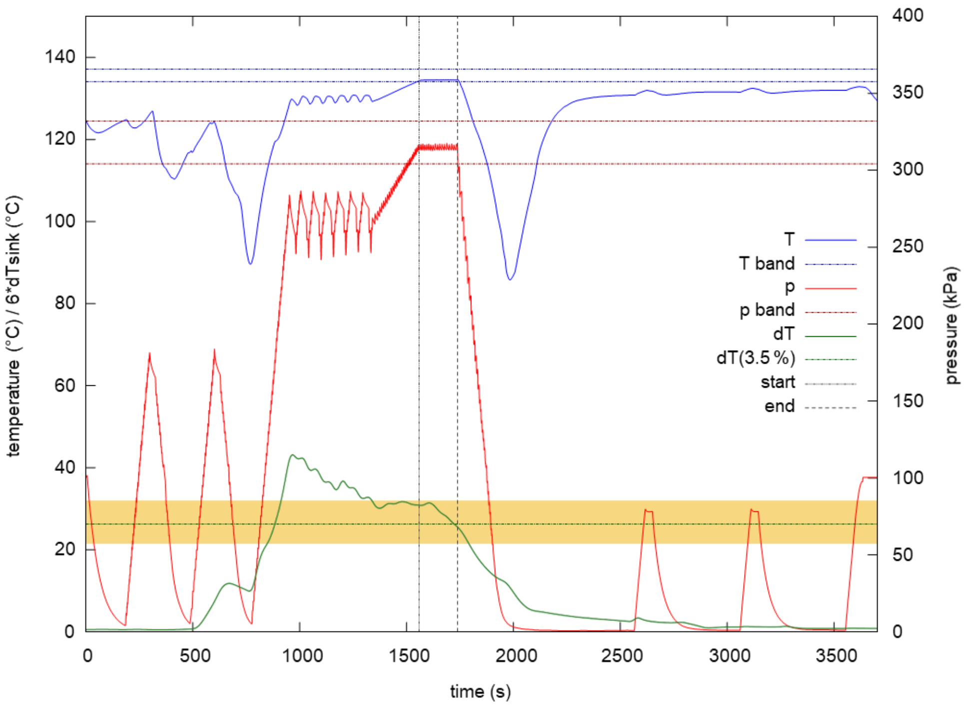

Figure 4: Plot of the data measured by the NCG sensor for a (conditional) ***PASS*** *process.*
In the holding phase NCG = 2.9 % (min) - 3.6 % (max).