


**Guideline for reviewers of CMC entries  
in the field of the CCM WG Pressure and Vacuum:  
Risk based approach**

The CCM WG PV proposes the following guideline for the effort of reviewing processes of CMC entries in the field of vacuum and pressure.

**1. General**




It is recommended to adjust the effort of review according to the risk describing the probability of occurrence and impact that the value of an uncertainty statement in the CMC line is too low or that the range of the measurand is in a critical range. Associated with the risk is the effort required to support the statement (high risk, high effort).

A traffic light scheme is applied.

<p>Red: High risk</p> <p>Yellow: Medium risk</p> <p>Green: Low risk</p>	
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The following table lists the required supporting documents and items for the different risks:

Table 1 Supporting documents and items for the different risks

Light	Risk	Required documents and items
	High	<ul style="list-style-type: none"> <li>Peer reviewed publication or technical peer review for the CMC under review</li> <li>Written overview<sup>1</sup> of the measurement standard (method, reference standards, traceability, uncertainty budget)</li> <li>CCM KC or RMO KC<sup>2</sup> if applicable<sup>3</sup> with <math>E_n &lt; 1</math> and transfer standard with suitable uncertainty<sup>4</sup></li> </ul>
	Medium	<ul style="list-style-type: none"> <li>Technical peer review or written overview of the measurement standard (method, reference standards, traceability, uncertainty budget)</li> <li>RMO KC<sup>5</sup> or hybrid comparison<sup>6</sup> with <math>E_n &lt; 1</math> and transfer standard with suitable uncertainty</li> </ul>
	Low	<ul style="list-style-type: none"> <li>SC or hybrid comparison with <math>E_n &lt; 1</math> and transfer standard with suitable uncertainty</li> <li>Traceability to another CMC entry or fundamental method</li> </ul>

CMCs of pressure cover the range from  $10^{-9}$  Pa to  $10^9$  Pa, i.e. 18 decades. In addition, different types of pressure,

- absolute pressures,
  - gauge pressures,
  - differential pressures
- and
- different physical states (gas or liquid)

have to be considered. Differential pressures with the line pressure at atmospheric pressure are categorized as gauge pressures.

For this reason, it is necessary to detail the traffic light scheme for different sectors:

- Absolute pressure up to 170 kPa
- Absolute pressure  $> 170$  kPa
- Gauge pressure gas
- Gauge pressure liquid

<sup>1</sup> This overview may refer to the peer reviewed publication(s) and needs not to repeat it/them.

<sup>2</sup> If no KC has been defined by the CCM WG PV in this pressure range, a supplementary comparison (SC) is sufficient.

<sup>3</sup> If the CMC line covers a new range and no partner is available for a comparison, this requirement is not applicable.

<sup>4</sup> The additional uncertainty due to the transfer standard should not exceed the uncertainty of measurand (pressure) by more than a factor 2.

<sup>5</sup> See footnote 2

<sup>6</sup> Needs to be peer reviewed and published on the RMO website or in a journal as open access paper.

E. Negative gauge pressure

F. Differential pressure

In the following:

$U_{rel}^H$	Relative uncertainty $k=2$ for limit between high and medium risk
$U_{rel}^L$	Relative uncertainty $k=2$ for limit between medium and low risk
$U_{rel}^*$	Relative uncertainty $k=2$ of applicant's CMC
$p$	Pressure

In the case that the CMC spans several ranges of risk, the CMC shall be reviewed in the highest occurring risk category.

## 2. Sector "A" (absolute pressure up to 170 kPa)

For Sector "A" (absolute pressure up to 170 kPa) the risks are classified as follows (see also graph):

Table 2 Criteria for high and low risk for Sector A (absolute pressure up to 170 kPa<sup>7</sup>)

Light	Risk	Relative uncertainties or pressure range	Applicable in range
●	High	Independent of uncertainty value: pressure range $< 10^{-6}$ Pa	$< 10^{-6}$ Pa
		$U_{rel}^* \leq U_{rel}^H$ $U_{rel}^H = 10^{-1-0.1618 \cdot (\log(p/Pa)+9)}$	$10^{-6}$ Pa $\leq p < 1$ Pa
		$U_{rel}^H = 10^{-2.456-0.4736 \cdot \log p/Pa}$	$1$ Pa $\leq p < 170$ kPa
●	Medium	$U_{rel}^H < U_{rel}^* \leq U_{rel}^L$	
●	Low	$U_{rel}^* > U_{rel}^L$ $U_{rel}^L = 10^{-0.824-0.147 \cdot (\log(p/Pa)+7)}$	for $10^{-6}$ Pa $\leq p < 10$ Pa
		$U_{rel}^L = 10^{-2-0.575 \cdot (\log(p/Pa)-1)}$	for $10$ Pa $\leq p < 170$ kPa

<sup>7</sup> If the range of the CMC entry spans across 170 kPa, use both Sector A and B.

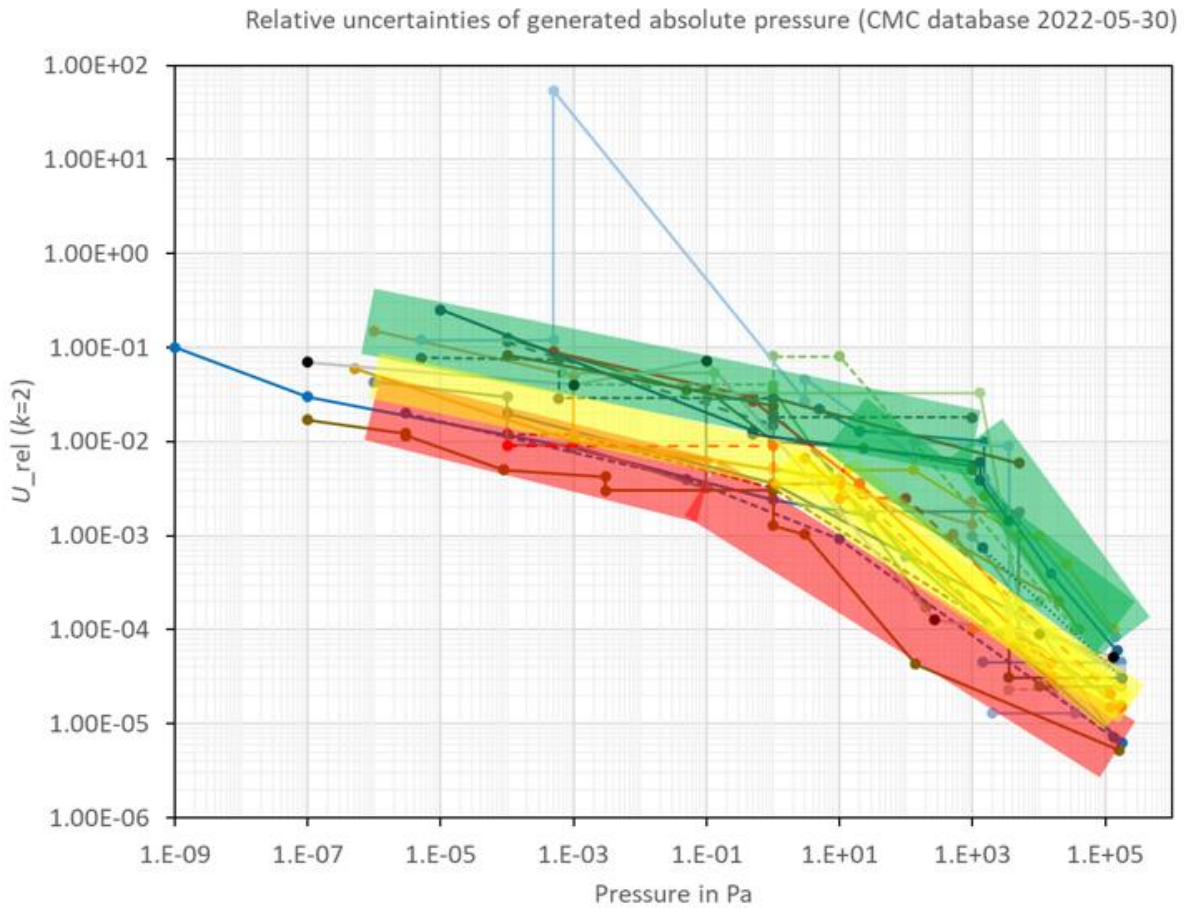


Figure 1 CMC entries as of 2022-05-31 with the risks for CMC review in dependence of pressure up to 170 kPa. Red: high risk, yellow medium risk, green low risk. Note that the uncertainties are relative ones and that the plot is on log-log scale.

The following table gives some values of the uncertainty limits for the different risks in Sector A.

Table 3 Some values of the two limits for high risk and low risk

$p$ in Pa	$1.0 \cdot 10^{-6}$	$1.0 \cdot 10^{-3}$	1	10	$10^3$	$10^5$
$U_{rel}^H$	$3.3 \cdot 10^{-2}$	$1.1 \cdot 10^{-2}$	$3.5 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$	$1.3 \cdot 10^{-4}$	$1.5 \cdot 10^{-5}$
$U_{rel}^L$	$1.1 \cdot 10^{-1}$	$3.9 \cdot 10^{-2}$	$1.4 \cdot 10^{-2}$	$1.0 \cdot 10^{-2}$	$7.1 \cdot 10^{-4}$	$5.0 \cdot 10^{-5}$

### 3. Sector "B" (absolute pressure > 170 kPa)

For Sector "B" (absolute pressure > 170 kPa) the risks are classified as follows:

Table 4 Criteria for high and low risk for Sector B (absolute pressure > 170 kPa<sup>8</sup>)

Light	Risk	Relative uncertainties
●	High	$U_{rel}^* \leq U_{rel}^H$ $U_{rel}^H = 2 \cdot 10^{-5}$
●	Medium	$U_{rel}^H < U_{rel}^* \leq U_{rel}^L$
●	Low	$U_{rel}^* > U_{rel}^L$ $U_{rel}^L = 4 \cdot 10^{-5}$

CMC entries in this sector range typically up to 7 MPa, in one case up to 10 MPa. So, they span less than two decades.

#### 4. Sector "C" (gauge pressure, gas)

For Sector "C" (gauge pressure, gas) the risks are classified as follows:

Table 5 Criteria for high and low risk for Sector C (gauge pressure, gas)

Light	Risk	Relative uncertainties	Applicable in range
●	High	Independent of uncertainty value: pressure range > 80 MPa	> 80 MPa
		Independent of uncertainty value: pressure range - 1 Pa < p < + 1 Pa	- 1 Pa < p < + 1 Pa
		$U_{rel}^* \leq U_{rel}^H$ $U_{rel}^H = 2.2 \cdot 10^{-2} \cdot (p/Pa)^{-0.772}$	1 Pa ≤ p < 10 <sup>3</sup> Pa
		$U_{rel}^H = 1.1 \cdot 10^{-4} \cdot (p/10^3 Pa)^{-0.324}$	10 <sup>3</sup> Pa ≤ p < 10 <sup>5</sup> Pa
		$U_{rel}^H = 2.4 \cdot 10^{-5} \cdot (p/10^5 Pa)^{-0.0376}$	10 <sup>5</sup> Pa ≤ p < 10 <sup>7</sup> Pa
		$U_{rel}^H = 2.0 \cdot 10^{-5} \cdot (p/10^7 Pa)^{0.392}$	10 <sup>7</sup> Pa ≤ p ≤ 8·10 <sup>7</sup> Pa
●	Medium	$U_{rel}^H < U_{rel}^* \leq U_{rel}^L$	
●	Low	$U_{rel}^* > U_{rel}^L$ $U_{rel}^L = 1.5 \cdot 10^{-1} \cdot (p/Pa)^{-0.803}$	1 Pa ≤ p < 10 <sup>3</sup> Pa
		$U_{rel}^L = 5.7 \cdot 10^{-4} \cdot (p/10^3 Pa)^{-0.374}$	10 <sup>3</sup> Pa ≤ p < 10 <sup>5</sup> Pa
		$U_{rel}^L = 1.0 \cdot 10^{-4} \cdot (p/10^5 Pa)^{-0.152}$	10 <sup>5</sup> Pa ≤ p < 10 <sup>7</sup> Pa
		$U_{rel}^L = 5.0 \cdot 10^{-5} \cdot (p/10^7 Pa)^{0.168}$	10 <sup>7</sup> Pa ≤ p ≤ 8·10 <sup>7</sup> Pa

<sup>8</sup> See footnote 7.

Table 6 Some values of the two limits for high risk and low risk

$p/\text{Pa}$	1	10	$10^2$	$10^3$	$10^5$	$10^7$	$8 \cdot 10^7$
$U_{\text{rel}}^{\text{H}}$	$2.2 \cdot 10^{-2}$	$3.7 \cdot 10^{-3}$	$6.3 \cdot 10^{-4}$	$1.1 \cdot 10^{-4}$	$2.4 \cdot 10^{-5}$	$2.0 \cdot 10^{-5}$	$4.5 \cdot 10^{-5}$
$U_{\text{rel}}^{\text{L}}$	$1.5 \cdot 10^{-1}$	$2.3 \cdot 10^{-2}$	$3.6 \cdot 10^{-3}$	$5.7 \cdot 10^{-4}$	$1.0 \cdot 10^{-4}$	$5.0 \cdot 10^{-5}$	$7.1 \cdot 10^{-5}$

The following figure shows the limits together with CMC entries as of 2022-05-31.

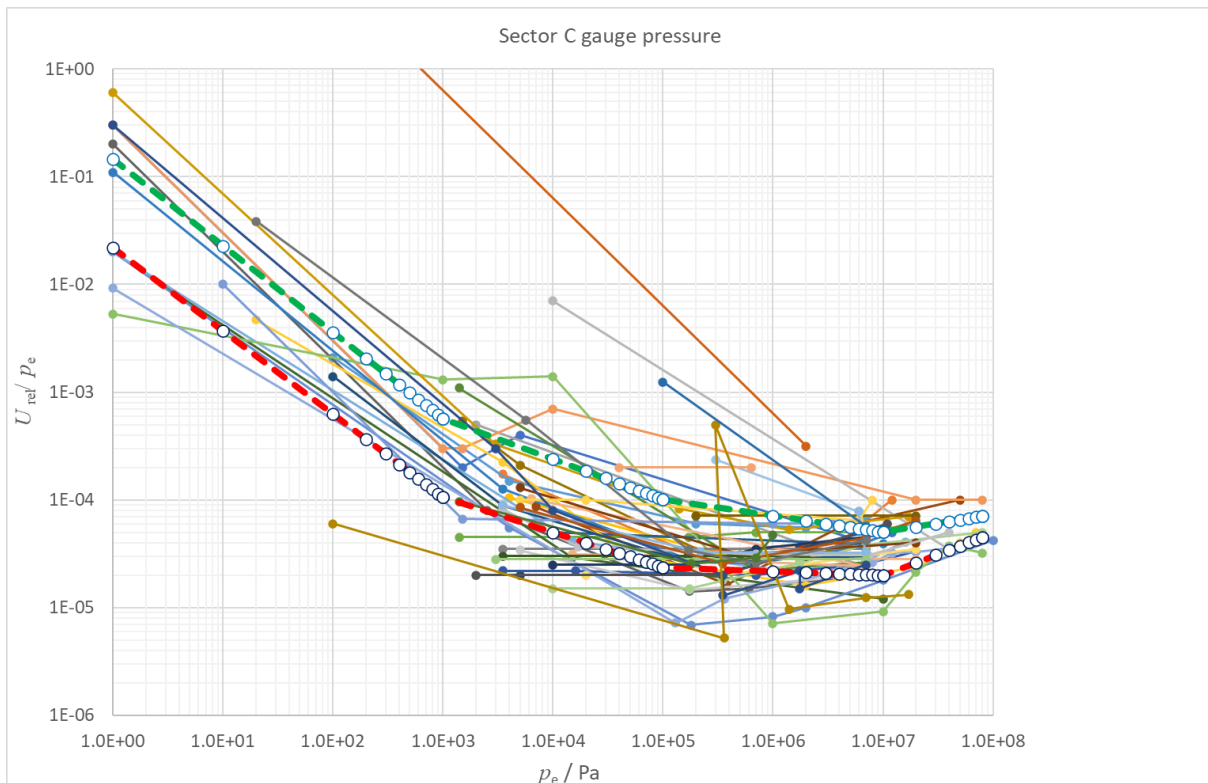


Figure 2 CMC entries as of 2022-05-31 with the future risks for CMC review in dependence of gauge pressure, gas. Red line: upper limit for high risk. Green line: lower limit for low risk. Note that the uncertainties are relative ones and that the plot is on log-log scale.

## 5. Sector "D" (gauge pressure, liquid)

For Sector "D" (gauge pressure, liquid) the risks are classified as follows:

Table 7 Criteria for high and low risk for Sector D (gauge pressure, liquid)

Light	Risk	Relative uncertainties	Applicable in range
●	High	Independent of uncertainty value: pressure range > 1 GPa $U_{rel}^* \leq U_{rel}^H$ $U_{rel}^H = 2 \cdot p^{-1} + 2.1 \cdot 10^{-5} + 1.5 \cdot 10^{-13} \cdot p$ $p$ in Pa	> 1 GPa all other
●	Medium	$U_{rel}^H < U_{rel}^* \leq U_{rel}^L$	
●	Low	$U_{rel}^* > U_{rel}^L$ $U_{rel}^L = 5 \cdot p^{-1} + 5 \cdot 10^{-5} + 3.5 \cdot 10^{-13} \cdot p$ $p$ in Pa	all

Table 8 Some values of the two limits for high risk and low risk

$p/Pa$	$10^5$	$3 \cdot 10^5$	$10^6$	$3 \cdot 10^6$	$10^7$	$3 \cdot 10^7$	$10^8$	$3 \cdot 10^8$	$10^9$
$U_{rel}^H$	$4.1 \cdot 10^{-5}$	$2.8 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$2.2 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$2.6 \cdot 10^{-5}$	$3.6 \cdot 10^{-5}$	$6.6 \cdot 10^{-5}$	$1.7 \cdot 10^{-4}$
$U_{rel}^L$	$1.0 \cdot 10^{-4}$	$6.7 \cdot 10^{-5}$	$5.5 \cdot 10^{-5}$	$5.3 \cdot 10^{-5}$	$5.4 \cdot 10^{-5}$	$6.1 \cdot 10^{-5}$	$8.5 \cdot 10^{-5}$	$1.6 \cdot 10^{-4}$	$4.0 \cdot 10^{-4}$

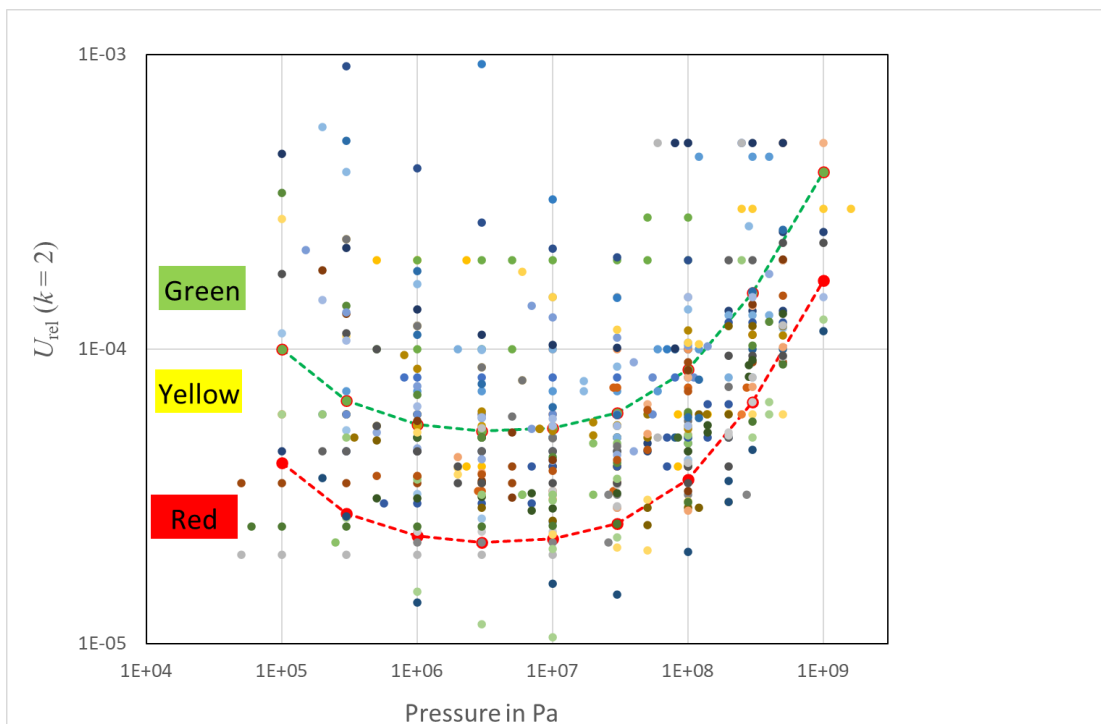


Figure 3 CMC entries as of 2022-05-31 with the future risks for CMC review in dependence of gauge pressure, liquid. Red line: upper limit for high risk. Green line: lower limit for low risk. Note that the uncertainties are relative ones and that the plot is on log-log scale.

## 6. Sector "E" (negative gauge pressure)

For Sector "E" (negative gauge pressure) the risks are classified as follows:

Table 9 Criteria for high and low risk for Sector E (negative gauge pressure)

Light	Risk	Relative uncertainties	Applicable in range
●	High	Independent of uncertainty value: pressure range $-1 \text{ Pa} < p < +1 \text{ Pa}$	$-1 \text{ Pa} < p < +1 \text{ Pa}$
		$U_{\text{rel}}^* \leq U_{\text{rel}}^{\text{H}}$	
		$U_{\text{rel}}^{\text{H}} = 3.5 \cdot 10^{-4} \cdot \left(\frac{p}{-1000 \text{ Pa}}\right)^{-0.51}$	$-100 \text{ kPa} \leq p \leq -1 \text{ kPa}$
		$U_{\text{rel}}^{\text{H}} = 1.9 \cdot 10^{-3} \cdot \left(\frac{p}{-100 \text{ Pa}}\right)^{-0.742}$	$-1 \text{ kPa} < p \leq -100 \text{ Pa}$
		$U_{\text{rel}}^{\text{H}} = 1.6 \cdot 10^{-1} \cdot \left(\frac{p}{-1 \text{ Pa}}\right)^{-0.957}$	$-100 \text{ Pa} < p \leq -1 \text{ Pa}$
●	Medium	$U_{\text{rel}}^{\text{H}} < U_{\text{rel}}^* \leq U_{\text{rel}}^{\text{L}}$	
●	Low	$U_{\text{rel}}^* > U_{\text{rel}}^{\text{L}}$	
		$U_{\text{rel}}^{\text{L}} = 4.7 \cdot 10^{-3} \cdot \left(\frac{p}{-1000 \text{ Pa}}\right)^{-0.751}$	$-100 \text{ kPa} \leq p \leq -1 \text{ kPa}$
		$U_{\text{rel}}^{\text{L}} = 3.0 \cdot 10^{-2} \cdot \left(\frac{p}{-100 \text{ Pa}}\right)^{-0.800}$	$-1 \text{ kPa} < p \leq -100 \text{ Pa}$
		$U_{\text{rel}}^{\text{L}} = 2.5 \cdot \left(\frac{p}{-1 \text{ Pa}}\right)^{-0.964}$	$-100 \text{ Pa} < p \leq -1 \text{ Pa}$

Table 10 Some values of the two limits for high risk and low risk for negative gauge pressures. Please, note that the value marked with a star\* is  $> 100 \%$ .

$p/\text{Pa}$	$-1 \cdot 10^{-5}$	$-7 \cdot 10^4$	$-3 \cdot 10^4$	$-1 \cdot 10^4$	$-1 \cdot 10^3$	$-1 \cdot 10^2$	-10	-1
$U_{\text{rel}}^{\text{H}}$	$3.3 \cdot 10^{-5}$	$4.0 \cdot 10^{-5}$	$6.2 \cdot 10^{-5}$	$1.1 \cdot 10^{-4}$	$3.5 \cdot 10^{-4}$	$1.9 \cdot 10^{-3}$	$1.8 \cdot 10^{-2}$	0.16
$U_{\text{rel}}^{\text{L}}$	$1.5 \cdot 10^{-4}$	$1.9 \cdot 10^{-4}$	$3.7 \cdot 10^{-4}$	$8.3 \cdot 10^{-4}$	$4.7 \cdot 10^{-3}$	$3.0 \cdot 10^{-2}$	$2.7 \cdot 10^{-1}$	2.5*



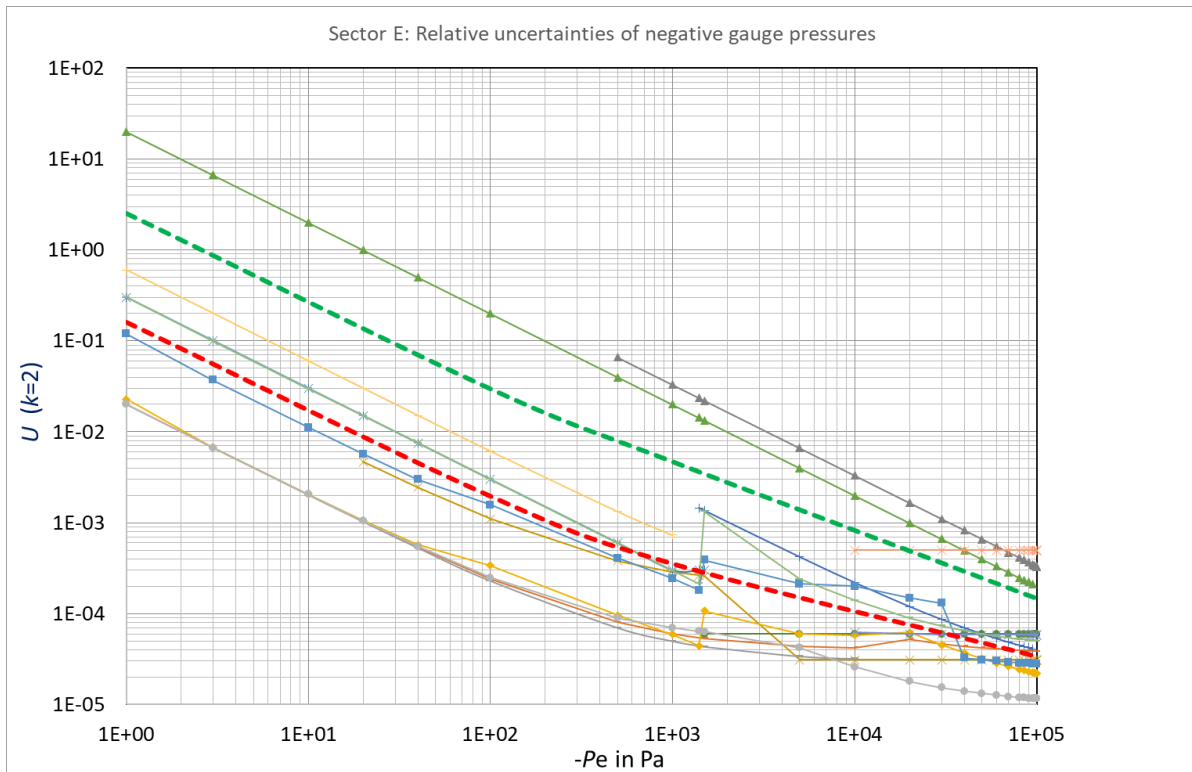


Figure 4 CMC entries as of 2022-05-31 with the future risks for CMC review in dependence of negative gauge pressure between -100 kPa and 0 kPa. Note that negative pressures have been converted to positive to show them on logarithmic scale. Red line: upper limit for high risk. Green line: lower limit for low risk.

### 7. Sector "F" (differential pressure):

It is difficult to set limits for uncertainties, because these vary with the line pressure. For this reason, any such CMC application in this sector must be reviewed on an individual basis. No recommendation in terms of risk can be given.