**Slovak Institute of Metrology**
Karloveská 63, 842 55 Bratislava 4, Slovak Republic
**Centre of Mass, Pressure and Flow**

tel: +421 2 60294322 fax: +421 2 60294332 e-mail: flow@smu.gov.sk

# CALIBRATION CERTIFICATE

## No.: 10227/290/143/11

| | |
|---|---|
| **Object of calibration:** | **Critical Nozzle** |
| **Type:** | Toroidal-Throat Venturi Nozzle |
| **Identification mark:** | xx-yyy-2000 |
| **Manufacturer:** | G. Kromschroeder AG**,** Germany |
| **Customer:** | xxxxxx,GmbH<br>yyyyy (zzzzzz), Germany |
| **Order No.:** | 420245 |
| **Place and date of calibration:** | SMU Bratislava, 09.12.2011 |
| **Number of pages:** | 3 |

This calibration certificate confirms the traceability to national standards, which realize the units of measurement in conformity with the International System of Units (SI.
Under the MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in Appendix C (for details see www.bipm.org).
The user is obliged to have the object recalibrated at appropriate intervals.

| **Place and date** | **Official stamp** | **Head of Centre** |
|---|---|---|
| 16.12.2011 | | Ing.Robert Spurný, CSc. |

**Conditions of calibration :**

The calibration was performed at two pressure levels measured at the nozzle entry of the purpose to achieve the parameters of critical nozzle ( value of volumetric flow rate $Q_{V,20,\mathrm{dry},1000}$ through the nozzle during the conditions of pressure on the nozzle entry $p_{\mathrm{abs}}$ = 1000 mbar by the temperature 20°C and relatively air humidity $\varphi$=0% and a correction factor $c_{pE}$ ) . The first pressure level is the pressure very similar to atmospheric conditions. The second level pressure is lower comparing to the first level in 10 kPa.
Test medium: air

**Environmental conditions:**

| | |
|---|---|
| Enviroment temperature : | (21,42 ± 0,19 ) °C |
| Atmospheric pressure: | (98682 ± 92) Pa |
| Air humidity : | (52 ± 2) % |

**Traceability:**

Measurements were performed by the National standard of flow and of delivered volume of gas ( by the primary standard with the bell, S.N. 334/1999 ).

**Procedure of calibration:**

Volumetric method with the flying start according to the operating procedure No. 18/230.

**Results of calibration:**

The following parameters were determined for nozzle calibration:

$\boldsymbol{Q_{V,20,dry,1000}}$ **= 1932,43 dm$^3$× h$^{-1}$**
$\boldsymbol{c_{p,E}}$ **= 1,05 × 10$^{-5}$ mbar$^{-1}$**
$\boldsymbol{U}$ **= 4,84 dm$^3$ × h$^{-1}$**

Warning:
The value of flow rate of nozzle is valid only by assumption that the hole of nozzle is not impure or mechanical damaged. Further assumption is, that difference of pressure needed for achieving of critical flow regime is created on the measuring line and gripping of nozzle in the test bench is tight.

For determination of volumetric flow rate $Q_{V,\mathrm{M}}$ is generally valid:

$$Q_{V,\mathrm{M}} = \frac{\rho_{\mathrm{D}}}{\rho_{\mathrm{M}}}\left(1+0{,}169*\chi_v\right)*\sqrt{\frac{T_{\mathrm{D}}}{293{,}15}}*\left[1+c_{p,E}*\left(p_{\mathrm{D}}-1000mbar\right)\right]*Q_{V,20,dry,1000}$$

For determination of mass flow rate $Q_{m\mathrm{M}}$ is generally valid:

$$Q_{m,\mathrm{M}} = \rho_{\mathrm{D}}\left(1+0{,}169*\chi_v\right)*\sqrt{\frac{T_{\mathrm{D}}}{293{,}15}}*\left[1+c_{p,E}*\left(p_{\mathrm{D}}-1000mbar\right)\right]*Q_{V,20,dry,1000}$$

where:

| | |
|---|---|
| $\boldsymbol{Q_{V,20,dry,1000}}$ | is the volumetric flow rate of dry air through the nozzle at 20°C and at absolute pressure 1000 mbar on the nozzle entry |
| $c_{p,E}$ | correction factor for absolute pressure dependency on the entry of critical nozzle |
| $p_{\mathrm{D}}$ | absolute pressure on the entry of nozzle |
| $T_{\mathrm{D}}$ | thermodynamic temperature on the entry of nozzle |
| $x_v$ | molar quotient of water steam for humid air |
| $\rho_{\mathrm{D}}$ *resp.* $\rho_{\mathrm{M}}$ | density of air |

The values $x_v$ , $\rho_D$ *resp.* $\rho_M$ are calculated by :
Giacomo, P.: Formel für die Bestimmung der Dichte von feuchter luft. Listed in: PTB – Mitteilungen 89, 4/79, S. 271, resp. in „PTB-Prüfregeln: Prüfstände mit kritischen Düsen für Luft“.

**Uncertainty of measurement:**

The reported expanded uncertainty of measurement is stated as the combined standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty of measurement has been determined in accordance with EA Publication EA-4/02 and GUM (Guide to the Expression of Uncertainty in measurement. BIPM/IEC/ISO/OIML, 1993, 1995).

**Person in charge:**

Dr. Vlastimil Zámečník