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Atmospheric
Measurement
Techniques
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Supplement of

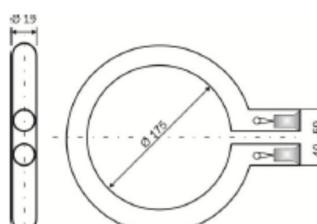
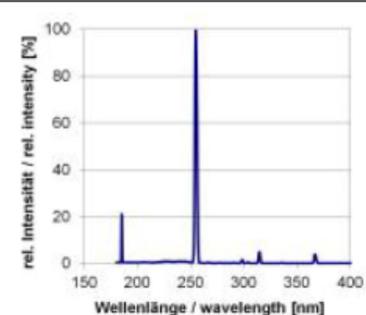
Calibration of an airborne HO_x instrument using the All Pressure Altitude-based Calibrator for HO_x Experimentation (APACHE)

Daniel Marno et al.

Correspondence to: Daniel Marno (daniel.marno@mpic.de) and Hartwig Harder (hartwig.harder@mpic.de)

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1 **Supplementary. Data sheets**

Stand: 26.02.14	Technisches Datenblatt					
UVN 50 N Ringstrahler di=175mm mit 200 mm Litze maximaler Lampenstrom IL=800 mA, PN Quarz						
Artikel-Nummer: 151 02501 0000						
1. Geometrische Daten <p> Gesamtlänge GL: ohne Kontaktstifte Leuchtlänge BL: Material Lampenrohr: QGR PS 19,0±0,4 x 1,4±0,2 x ... Sockelmaße: 2x x kundenspez. Markierung: nein </p> 						
2. Elektrische Daten <p> - Lampenstrom: 0,8 A - Lampenspannung: 62 ± 3 V - Lampenleistung: 50 W Vorschaltgerät des Kunden - Typ: EVG UVT 40WHO ACHTUNG: Rücksprache notwendig, falls ein anderes VG verwendet wird! </p>						
3. Betriebsweise <p> - Brennlage: beliebig - Lampenrohrttemperatur: min. 40°C, optimal 40-50°C, max. 60°C </p>						
4. Strahlenphysikalische Daten <p> Messabstand: Bestrahlungsstärke: mW/cm² bei 254 nm UVC Leistung: 15 W UVC 100 Stunden-Wert, gemessen frei brennend unter Laborbedingungen. Unter realen Bedingungen können die Werte teilweise extrem abweichen. </p> <p> garantierte Lebensdauer: 6000 h Nutzlebensdauer: 6000 h Leistungsabfall nach Nutzlebensd.: 35 % Betriebsweise: Dauerbetrieb max. 1 Schaltung pro Tag </p>  <p> Die Nutzlebensdauer ist abhängig von Anlagenauslegung und Betriebsweise (EIN-AUS-Schaltzyklen, Kühlung, Verschmutzung). Die tatsächliche Strahlerleistung ist vom gewählten Vorschaltgerät abhängig. Durch Änderung des Strahlerstromes kann nach Rücksprache mit uns eine andere als die oben angegebene Leistung eingestellt werden. Eine funktionsgerechte Anwendung dieses Strahlers ist nur in speziellen, dafür geeigneten Anlagen gewährleistet. Der sachgemäße Einsatz kann deshalb nur durch den jeweiligen Gerätehersteller erfolgen. Kundenspezifische Sonderausführungen auf Anfrage. </p> <p>ACHTUNG: Die von diesem Strahler ausgehende Strahlung ist schädlich für Haut und Augen. Deshalb dürfen sie nur in dafür vorgesehenen Anlagen betrieben werden, die für einen ausreichenden Strahlenschutz sorgen. Arbeitsschutzzvorschriften sind zu beachten!</p>						

2 **Figure S.1.:** The specifications of the UV ring lamp used in APACHE, developed by uv-technik Speziallampen GmbH, Gewerbegbiet Ost 6, 98704, Wolfsberg, Germany.



NATIONAL PHYSICAL LABORATORY

Teddington Middlesex UK TW11 0LW Telephone +44 20 8977 3222

Certificate of Calibration

NPL PRIMARY REFERENCE MATERIAL



4002

Cylinder Number: 2336

This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to the SI system of units and/or to units of measurement realised at the National Physical Laboratory or other recognised national metrology institutes. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CUSTOMER:

Max-Planck-Institut für Chemie

ADDRESS:

Atmospheric Chemistry, Hahn-Meitner-Weg 1,
55128 Mainz, Germany

CALIBRATION DATE: 27 September 2017

AMOUNT FRACTION:

Component	Amount fraction / ($\mu\text{mol/mol}$)
Nitrogen monoxide	5.004 ± 0.025
Nitrogen	Balance

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a coverage probability of approximately 95 %. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

METHODS: Preparation: gravimetry; Analysis: non-dispersive ultraviolet

TRACEABILITY: The values on this certificate are traceable to NPL Primary Standards

EXPIRY: Certificate valid for 1 year from the date of issue

PRESSURE: Fill pressure: 100 bar; Minimum utilisation pressure: 5 bar

STORAGE: No special precautions are required

HANDLING: Refer to ISO 16664

OUTLET: BS341 No. 14 valve

INTENDED USE: Calibration standard

Reference: 2017060311

Date of issue: 28 September 2017

Signed:

(Authorised Signatory)

Name: Dr P J Brewer

(on behalf of NPLML)

Checked by:

Page 1 of 1



This certificate is consistent with the capabilities that are included in Appendix C of the MRA drawn up by the CIPM. Under the MRA, all participating institutes recognise the validity of each other's calibration and measurement certificates for the quantities, ranges and measurement uncertainties specified in Appendix C (for details see <http://www.bipm.org>).

NPL/CD5-09/13

5

- 6 **Figure S.2.:** National Physical Laboratory – NO standard used for actinic flux density
7 calibration of mercury lamp that was used for calibration of HORUS instrument
8 in Experiment A.

Ø273 µm Core TECS-Coated Multimode Optical Fiber

Item #	Wavelength Range	Hydroxyl Content	Core Diameter	Cladding Diameter	Coating Diameter	Buffer Diameter	Core/Cladding	Coating ^a	Buffer	Proof Test
FG273UEC	250 - 1200 nm ^b	High OH	273 ± 10 µm	300 ± 6 µm	330 ± 10 µm	400 ± 30 µm	Pure Silica / Fluorine-Doped Silica	TECS Hard Fluoropolymer	Tefzel	≥100 kpsi
FG273LEC	400 - 2200 nm	Low OH								
Item #	NA	Pulsed ^c	CW ^d	Max Attenuation @ 808 nm	Max Core-Cladding Offset	Max Core-TECS Offset	Bend Radius	Operating Temperature	Strip Tool	Core Index
FG273UEC	0.22 ± 0.02	1.87 MW	0.37 kW	10 dB/km	4 µm	7 µm	16 mm	32 mm	-60 to 125 °C	T14S1B ^e See Table in Overview Tab
FG273LEC										Proprietary ^f

a. This coating acts as a second cladding with an NA of 0.39, which is calculated from the index difference between the TECS coating to the core, rather than between the silica cladding and the TECS coating/second cladding.

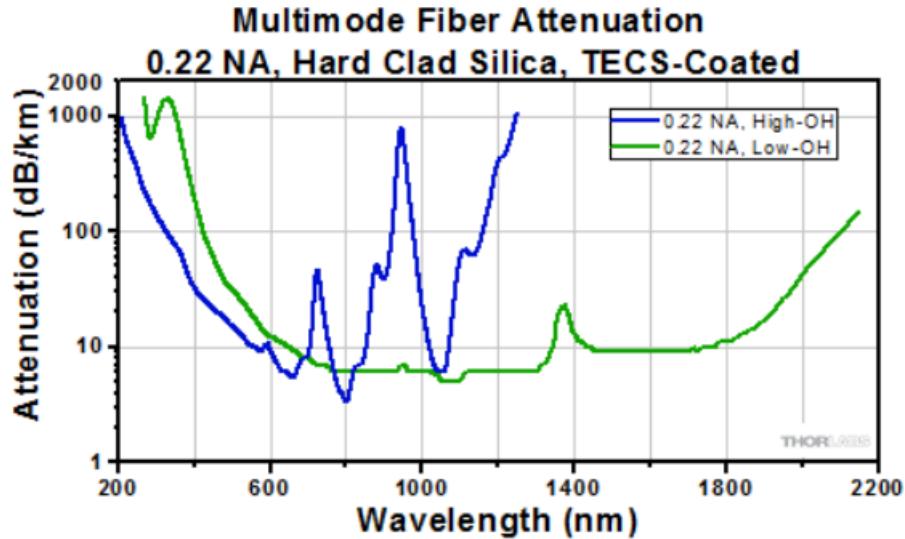
b. Polarization may occur at wavelengths below 300 nm. We also offer [solarization-resistant multimode fiber](#).

c. Based on 5 GW/cm² for 1064 nm Nd:YAG laser with 10 ns pulse length and input spot size equal to 80% of the core diameter.

d. Based on 1 MW/cm² for 1064 nm Nd:YAG laser and input spot size equal to 80% of the core diameter.

e. This tool will strip off the buffer for termination to the coating.

f. We regret that we cannot provide this proprietary information.



11 **Figure S.3.:** Specifications of coated silica fiber used for transmittance of 308 nm light through
12 the HORUS instrument. (Information taken from specification listings, Thorlabs
13 GmbH, Europe, Germany, www.thorlabs.de)

Hessisches Landesamt für Naturschutz, Umwelt und Geologie

HESSEN



Prüfbericht der Kalibrierung

PB-Nr: 24B04_S/N0711521534_20190219

Auftraggeber:
Max Planck-Institut für Chemie
Hahn-Meitner-Weg 1
55128 Mainz

Auftragsnummer: n.n.
Prüfgegenstand: O₃-Generator
Zustand: gebraucht
Hersteller: Thermo Fisher Scientific Inc.
Modell: 49i.PS
Serien-Nr.: 711521534
Messbereich: 0-1 ppm O₃
Ausgangssignal: seriell
Eingangsdatum: 11.02.2019
Prüfdatum: 14.02.2019
Ausgangsdatum: 19.02.2019

Die Überprüfung erfolgte mit selbsthergestellten Prüfgasen nach den Vorgaben des ISO-Guide 34.

Rückführung: UBA
zuletzt am 24.05.2018
Messunsicherheit: 2%

Die Prüfergebnisse beziehen sich nur auf den zur Prüfung vorgelegten Gegenstand.
Die Ergebnisse des Berichts gelten für den Gegenstand wie vom Kunden erhalten.

Für die Einhaltung einer angemessenen Frist zur Wiederholung der Überprüfung ist der Benutzer verantwortlich.

Dieser Prüfbericht darf ohne die schriftliche Zustimmung des Unterzeichners nicht auszugsweise vervielfältigt werden.

Datum:

22 FEB. 2019

Prof. Dr. Stefan Jacobi
Technische Leitung

Jens Kettenbach
Bearbeiter



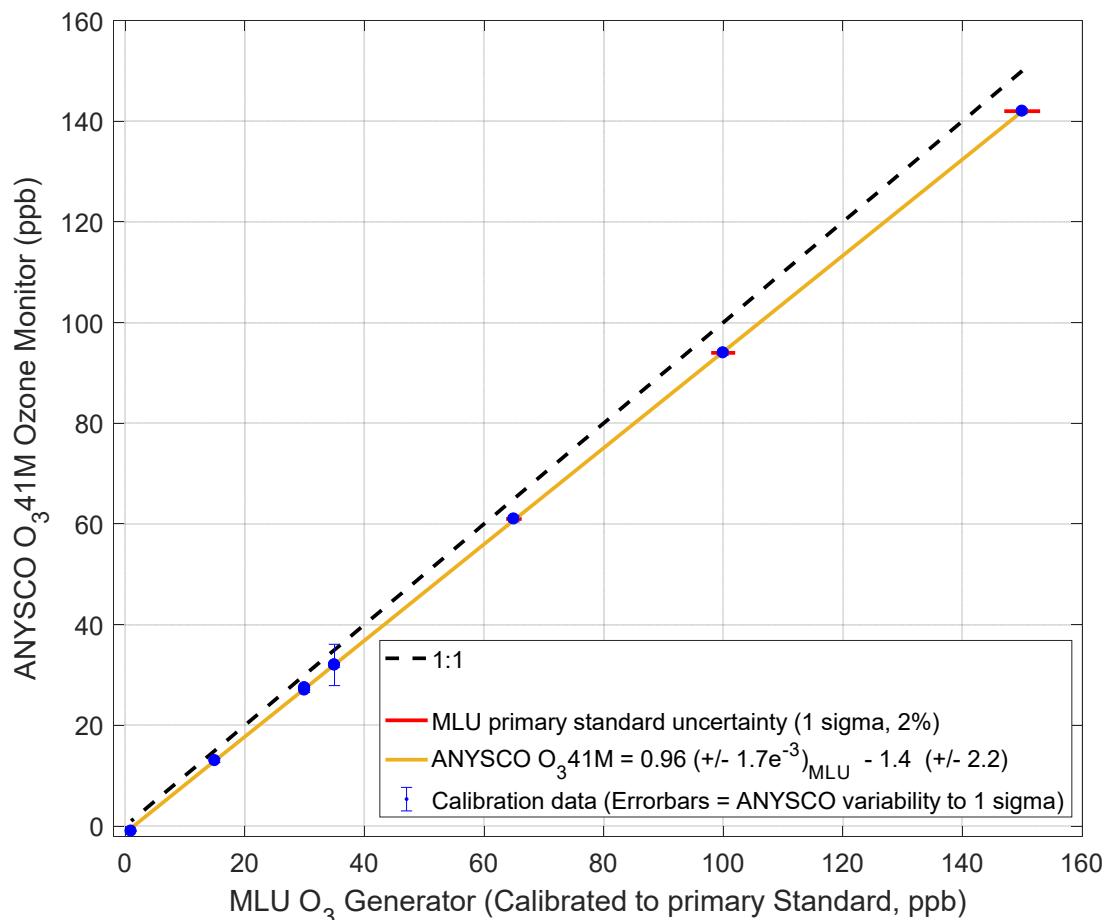
Deutsche
Akkreditierungsstelle
D-PL-14551-01-00

Rheingaustraße 186, 65203 Wiesbaden
Tel. 0611-6939-0, Fax 0611-6939-236

HLNUG
Hessisches Landesamt für
Naturschutz, Umwelt und Geologie
Dezernat I2

Seite 1 von 4

23 **Figure S.4.:** Certificate of the Fluke Ozone generator uncertainty compared to the Deutsche
24 Akkreditierungsstelle primary standard at Hessisches Landsamt für
25 Naturschutz, Umwelt und Geologie, Rheingaustraße 186, 65203, Wiesbaden.



26 **Figure S.5.:** The calibration of the ANYSCO Ozone monitor against the MLU ozone generator
 27 which was calibrated to primary standard.

28

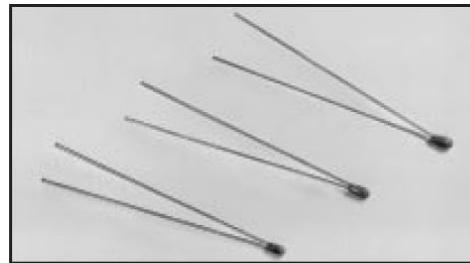


NTC THERMISTORS: TYPE EC95

INTERCHANGEABLE CHIP THERMISTOR

DESCRIPTION:

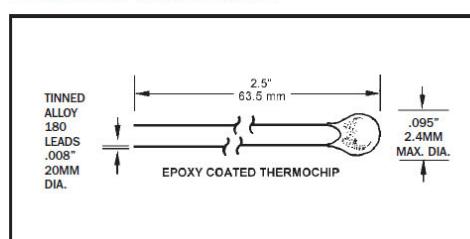
Epoxy Coated interchangeable chip thermistors with bare tinned 180 alloy lead-wires.



FEATURES:

- Precision, solid state temperature sensor
- Interchangeability down to $\pm 0.1^\circ\text{C}$
- Suitable for use over range of -80°C to $+150^\circ\text{C}$
- High sensitivity greater than $-4\%/\text{C}$ at 25°C
- Suitable for temperature measurement, control and compensation
- High reliability and stability over interchangeable range
- Most popular R-vs-T curves are available
- Resin coated for good mechanical strength and resistance to solvents
- $.008''$ (.2 mm) dia. bare tinned 180 alloy lead-wires

DIMENSIONS:



Select appropriate part number below for resistance and temperature tolerance desired

R _{25°C}	MATERIAL SYSTEM	± .2°C -20°C to +50°C	± .1°C 0°C to 70°C	± .2°C 0°C to 70°C
100	Q	EC95Q101U		
300	Q	EC95Q301U		
1000	R	EC95R102U		EC95R102W
1000	S	EC95S102U		EC95S102W
2252	F	EC95F232U	EC95F232V	EC95F232W
3000	F	EC95F302U	EC95F302V	EC95F302W
5000	F	EC95F502U	EC95F502V	EC95F502W
10000	F	EC95F103U	EC95F103V	EC95F103W
10000	Y	EC95Y103U	EC95Y103V	EC95Y103W
30000	H	EC95H303U	EC95H303V	EC95H303W
50000	G	EC95G503U	EC95G503V	EC95G503W
100000	G		EC95G104V	EC95G104W

RS 151-215 = EC95F302W
RS 151-221 = EC95F502W
RS 151-237 = EC95F103W
RS 151-243 = EC95G104W

OPTIONS:

Consult factory for availability of options:

- Other resistance values in the range of 100Ω - $100k\Omega$
- Other tolerances or ranges
- Alternative lead-wires or lengths
- Non standard R-vs-T curves
- Controlled dimensions

DATA:

THERMAL AND ELECTRICAL PROPERTIES:

Dissipation constant:.....(still air) 1 mW/ $^\circ\text{C}$
(stirred oil) 8 mW/ $^\circ\text{C}$

Thermal time constant:.....(still air) 10 sec.
(stirred oil) 1 sec.

Maximum power at 25°C 75mW
(derated from 100% at 25°C to 0% at 100°C)

29 **Figure S.6.:** Datasheet for the NTC-EC95302V thermistor used for temperature monitoring in
30 APACHE.

31

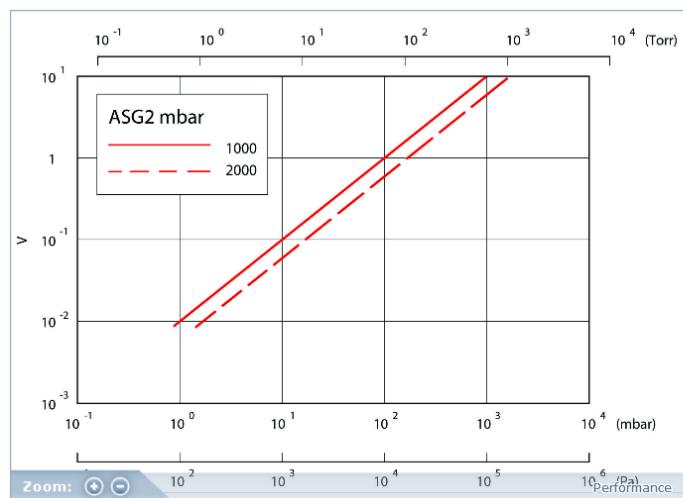
32

33

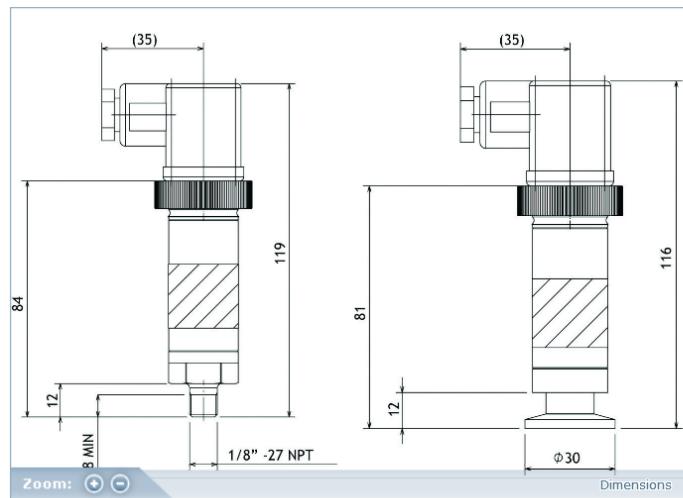
Technical Data

Full scale pressure range	ASG2-1000, 1000 to 1 mbar ASG2-2000, 2000 to 1 mbar
Accuracy	$\pm 0.2\%$ full scale
Stability	$\pm 0.1\%$ full scale
Temperature coefficient	$\pm 0.03\%$ full scale per $^{\circ}\text{C}$
Power supply	12 to 32 V d.c.
Maximum power	0.1 W
Output signal	0 to 10 V d.c. linear
Output impedance	5 k (Ohms)
Minimum load	>10 (Ohms)
Adjustments	Set full scale and set zero
Temperature range	
Compensated	-10 to +50 $^{\circ}\text{C}$
Operating / Storage	-40 to +80 $^{\circ}\text{C}$
Materials exposed to vacuum	Stainless steel 316L, Hastelloy C276
Internal volume	NW16 2.78 cm ³ 1/8" NTP 2.74 cm ³
Weight	NW16 150 g 1/8" NTP 130 g
Electrical connector	4 pin Din 43650 Form A
Vacuum fitting	NW16 or 1/8" NTP
Enclosure rating	IP65

Performance



Dimensions



34 **Figure S.7.:** Datasheet for the Edwards ASG2-1000 pressure sensor used for pressure monitoring in APACHE.
35

Technical specifications

IN-FLOW 'HIGH-FLOW' F-106AI



Measurement / control system		Industrial Style Mass Flow Meter for High Gas Flow
Flow range, based on N ₂ (intermediate ranges available)	min. 1...50 m ³ _n /h max. 10...500 m ³ _n /h	<ul style="list-style-type: none"> High accuracy, excellent repeatability Virtually pressure and temperature independent Compact design Rugged, weatherproof housing (IP65, dust and waterproof) "Wafer type" for mounting between flanges (DN40 / 1½")
Accuracy (incl. linearity) (based on actual calibration)	±1% FS	
Turndown	1:50	
Multi fluid capability	storage of max. 8 calibration curves	
Repeatability	< 0,2% Rd	
Response time	typical: 0,5 seconds	
Operating temperature	-10...+70°C; for ATEX cat. 3 and FM Class 1 Div 2 : 0...50°C	
Temperature sensitivity	zero: < 0,05% FS/°C; span: < 0,05% Rd/°C	
Pressure sensitivity	0,1% Rd/bar typical N ₂ ; 0,01% Rd/bar typical H ₂	
Leak integrity, outboard	tested < 2 x 10 ⁻⁹ mbar l/s He	
Attitude sensitivity	max. error at 90° off horizontal 0,2% FS at 1 bar, typical N ₂	
Warm-up time	30 min. for optimum accuracy 2 min for accuracy ± 2% FS	

Mechanical parts	
Material (wetted parts)	stainless steel 316L or comparable
Pressure rating	up to 40 bar abs (PN10, 16, 40); for hazardous gases such as O ₂ , H ₂ , etc. do not exceed operating pressure of 10 bar; for higher pressure select a flanged type MFM, series F-107/F-117.
Process connections	Wafer type, for mounting between flanges according to DIN DN50 or ANSI 2"
Seals	standard: Viton®; options: EPDM, Kalrez® (FFKM)
Weight	4,6 kg
Ingress protection (housing)	IP65

Electrical properties			
Power supply	+15...24 Vdc		
Max. power consumption	Supply 15 V 24 V	at voltage I/O 95 mA 65 mA	at current I/O 125 mA 85 mA
PROFIBUS DP	add 53 mA (15 V supply) or 30 mA (24 V supply)		
DeviceNet™	add 48 mA (24 V supply)		
Analog output/command	0...5 (10) Vdc or 0 (4)...20 mA (sourcing output)		
Digital communication	standard: RS232; options: PROFIBUS DP, PROFINET, DeviceNet™, Modbus RTU or ASCII, FLOW-BUS		

Electrical connection	
Analog/RS232	8 DIN (male);
PROFIBUS DP	bus: 5-pin M12 (female); power: 8 DIN (male);
PROFINET	bus: 2 x 5-pin M12 (female) (in/out); power: 8 DIN (male);
Devicenet™	5-pin M12 (male);
FLOW-BUS/Modbus-RTU/ASCII	5-pin M12 (male)

36

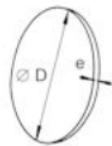
37 **Figure S.8.: Datasheet for the Bronkhorst F-106AI-PAD-03-V mass flow controller to regulate
38 the high flows through APACHE.**

AMPOR® - BRONZE - P BC (Scheiben)

Aufbau der Materialbezeichnung

Die Materialbezeichnung ist wie folgt aufgebaut:
Typ . Dicke e (x 10) . Filterklasse.

Beispiel: die Materialbezeichnung einer Scheibe mit einem Durchmesser D von 114 mm und einer Dicke e von 2 mm der Filterklasse 10 lautet:
AMPOR-P BC 114.20.10.



Standardabmessungen (Überblick)

<u>Typ BC</u>	<u>Durchmesser D (mm)</u>	<u>Filterfläche (cm²)</u>	<u>Dicke e (mm)</u>	<u>Filterklasse</u>
006	6	0,3	2-3	03-60
013	13	1,3		
021	21	3,5		
030	30	7,0		
042	42	14,0		
060	60	28,0		
090	90	63,5		
114	20	102,0		
250	250	450,0		
Filterklasse 03-30: Toleranz js 15, Filterklasse 40 und 60: k 15				

<u>Temperatur</u>	<u>max. zulässige Temperatur (°C)</u>	<u>Anmerkungen</u>
bei Zinnlötzung	100	Mit Zinn verbundene Teile dürfen auf keinen Fall über 100°C zum Einsatz kommen.
bei Hartlötzung	150	-
an der Luft	150	-
im Reduktionsmedium	abhängig vom Medium	In CO ₂ z.B. bis zu 400°C. Es ist aber die Abschwächung der mechanischen Eigenschaften des Werkstoffs unter dem Temperatureinfluss zu berücksichtigen.
Koeffizient der linearen Ausdehnung (1/°C): 18,4 × 10 ⁻⁶		

© by amtag

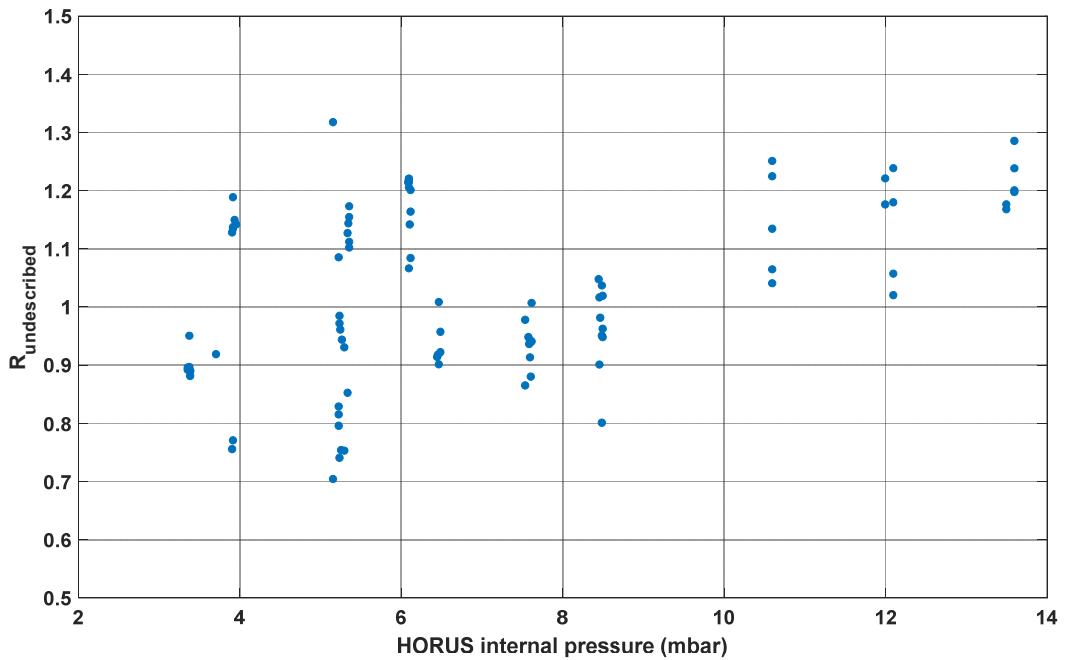


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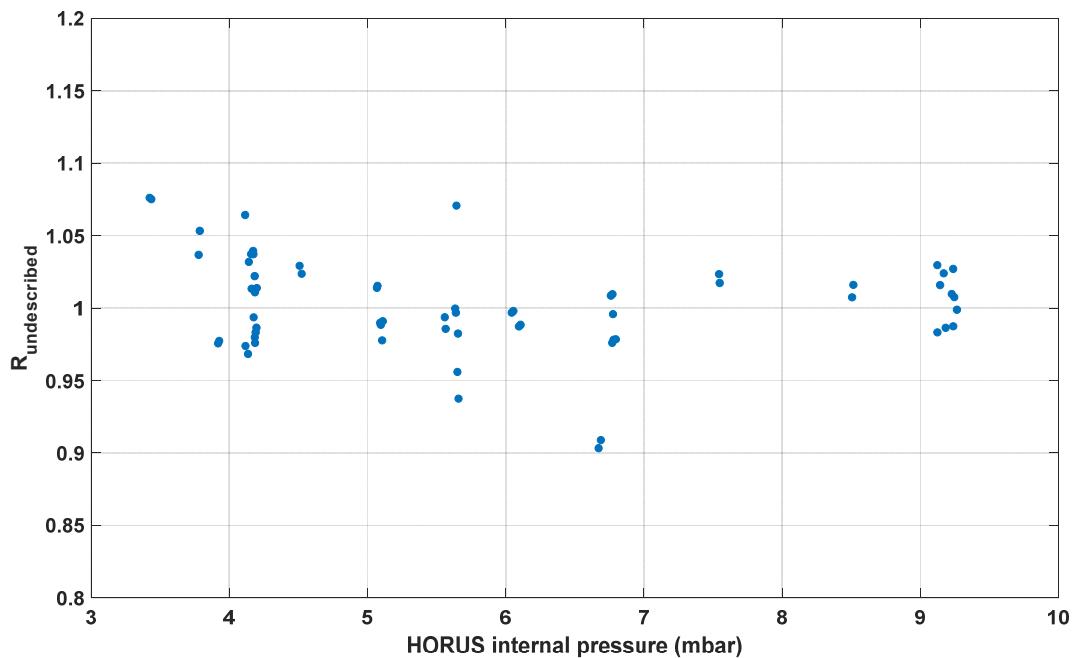
Lise-Meitner-Str. 2 • 40670 Meerbusch
Telefon: (02159) 69 599-0
Telefax: (02159) 69 599-33
www.amtag.de • info@amtag.de

39

40 **Figure S.9.:** Datasheet for the Bronze alloy AMPOR sinter filter from amtag. Company
41 address found on the data sheet.



42 **Figure S.10.:** $R_{\text{undescribed}}$ fraction plotted against HORUS internal pressure. Taken from
 43 calibration of the HORUS instrument setup (OMO-ASIA 2015 campaign)
 44 with APACHE.



45 **Figure S.11.:** $R_{\text{undescribed}}$ fraction plotted against HORUS internal pressure. Taken from
 46 calibration of the HORUS instrument setup (CAFÉ-AFRICA 2018 campaign)
 47 with APACHE.

48