



**CAMPBELL
SCIENTIFIC**
WHEN MEASUREMENTS MATTER

涡动通量系统的野外维护:
数据采集器, 三维超声风速仪, 红外气体分析仪

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2019年8月, 北京

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- › 4. 闭路系统 Zero/Span 操作演示
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1. 涡度通量系统的野外维护

数据采集器及其它电子设备



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定期更换机箱内部的干燥剂



无凝结条件是保证电子设备长期安全可靠运行的重要保证!

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远程或现场访问数据采集器的状态信息

```

Status Summary v
2019/7/10 8:25:36 v

Datalogger Information v
Reported Station Name: 5601.
OS Version: CR3000.Std.32.03.
OS Date: 08/03/2018.
OS Signature: 64273.
Panel Temperature: NAN °C.
Memory: 4194304 bytes.
Watchdog Errors: 17685 - Reset this value. If errors continue, contact Campbell Scientific.

Program Information v
Current Program: .
Start Time: 2009/5/27 21:16:27.
Run Signature: 43690.
Program Signature: 0.
Results for Last Program Compiled: Warning: Default Settings might have been restored.
No Program.
Low Battery, unable to calibrate.
Memory Free: 3846364 bytes.

Program Errors .
Program Errors: 2.
Skipped Scans: 0.
Skipped System Scans: 0.
Skipped Records in :
Variable Out of Bounds: 0.

Battery Information v
Battery Voltage: 0.00 - The battery voltage is low.
Lithium Battery: 3.45.
Number of times the datalogger's 12V supply has dropped below operating threshold: 37118 - Check your battery
Number of times voltage has dropped below 5V: 0.

Card Information v
Card Status: No Card Present.
    
```



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部分极端情况



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三维超声风速仪



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判断三维超声读数的合理范围

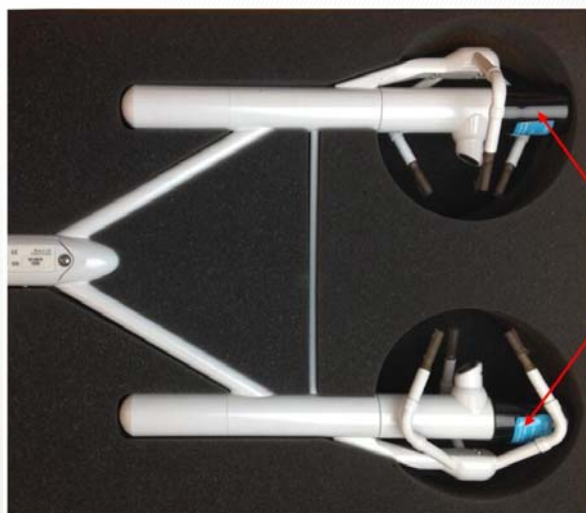
- CSi对每一台CSA标准
- 对于Ux, Uy, Uz 符合指标
- 对于Ts, 可以通过Ts值是否合理

$$T_s = T(1 + 0.51q)$$

| | | | | | | | |
|---------|---------|--------|---------|---------|---------|-----|---|
| -0.1751 | -0.1740 | 0.0584 | 36.6339 | 19.3166 | 20.2479 | 000 | 0 |
| -0.1729 | -0.1665 | 0.0513 | 36.6973 | 19.3081 | 20.0976 | 000 | 0 |
| -0.1734 | -0.1533 | 0.0561 | 36.6069 | 19.2545 | 20.0480 | 000 | 0 |
| -0.1646 | -0.1568 | 0.0609 | 36.5616 | 19.1610 | 20.1010 | 000 | 0 |
| -0.1791 | -0.1593 | 0.0610 | 36.5444 | 19.1091 | 20.0328 | 000 | 0 |
| -0.1686 | -0.1726 | 0.0548 | 36.5878 | 19.1419 | 20.0664 | 000 | 0 |
| -0.1494 | -0.1794 | 0.0652 | 36.6001 | 19.1143 | 19.9889 | 000 | 0 |
| -0.1385 | -0.1924 | 0.0611 | 36.4764 | 19.0321 | 19.8076 | 000 | 0 |
| -0.1035 | -0.1581 | 0.0902 | 36.5865 | 19.2117 | 19.9689 | 000 | 0 |
| -0.1315 | -0.1841 | 0.1013 | 36.4243 | 18.9577 | 19.7309 | 000 | 0 |
| -0.1289 | -0.1659 | 0.1009 | 36.3701 | 18.9806 | 19.7878 | 000 | 0 |
| -0.1281 | -0.1570 | 0.0815 | 36.3643 | 18.9607 | 19.7129 | 000 | 0 |
| -0.1500 | -0.1690 | 0.0869 | 36.3755 | 18.9131 | 19.7733 | 000 | 0 |
| -0.1583 | -0.1687 | 0.0856 | 36.4629 | 18.9198 | 19.6508 | 000 | 0 |
| -0.1223 | -0.1716 | 0.0835 | 36.1544 | 18.9792 | 19.6570 | 000 | 0 |
| -0.1295 | -0.1626 | 0.0960 | 36.0214 | 18.7476 | 19.6760 | 000 | 0 |
| -0.1252 | -0.2007 | 0.0902 | 36.2178 | 18.9097 | 19.5441 | 000 | 0 |
| -0.1105 | -0.1805 | 0.1093 | 36.0469 | 18.5384 | 19.5846 | 000 | 0 |
| -0.0855 | -0.2075 | 0.0660 | 36.4911 | 18.9955 | 20.1023 | 000 | 0 |
| -0.1012 | -0.1756 | 0.0765 | 36.7148 | 18.9912 | 20.0220 | 000 | 0 |
| -0.1155 | -0.1710 | 0.0628 | 36.2566 | 19.0000 | 19.8123 | 000 | 0 |
| -0.1220 | -0.1854 | 0.0780 | 36.3317 | 18.8116 | 19.6682 | 000 | 0 |
| -0.1473 | -0.1867 | 0.0662 | 36.2504 | 18.8062 | 19.6915 | 000 | 0 |
| -0.1268 | -0.1814 | 0.0663 | 36.6652 | 18.9019 | 20.1731 | 000 | 0 |



运输安全



Protective shipping bumpers



运输安全



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三维超声诊断值

Sonic anemometer diagnostic flags -- not connected

| Flag Status | Description |
|-------------|-------------------------------------|
| N/A | Low amplitude ok |
| N/A | High amplitude ok |
| N/A | Signal lock ok |
| N/A | Delta temperature ok |
| N/A | Sonic is running |
| N/A | Sonic head calibration signature ok |



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三维超声防雨网

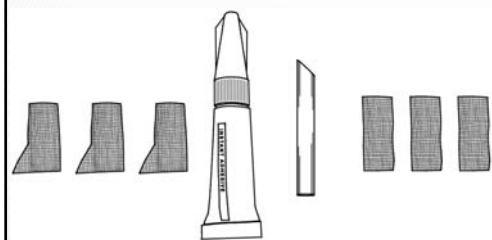


FIGURE 9-2. PN 28902 CSAT3 Sonic Wick Spares Kit contents

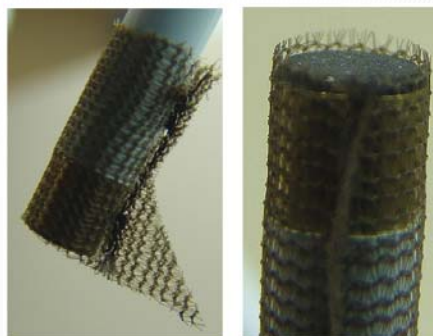


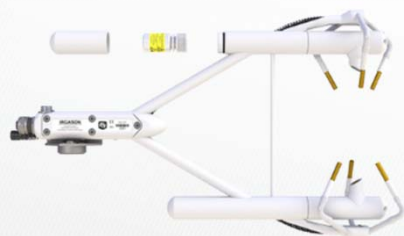
FIGURE 9-1. Proper location of the sonic top wick (left) and bottom wick (right)



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红外气体分析仪

› EC150/IRGASon/EC155



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分析仪诊断值

Gas analyzer diagnostic flags -- not connected

| Flag Status | Description |
|-------------|------------------------------------------|
| N/A | No diagnostic flags are set |
| N/A | No general system fault |
| N/A | Gas analyzer is running |
| N/A | Motor speed within limits |
| N/A | TEC temperature within limits |
| N/A | Source power within limits |
| N/A | Valid source temperature |
| N/A | Source current within limits |
| N/A | Gas head powered |
| N/A | Gas input data in sync with home pulse |
| N/A | Valid ambient temperature |
| N/A | Valid ambient pressure |
| N/A | CO2 I within limits |
| N/A | CO2 Io within limits |
| N/A | H2O I within limits |
| N/A | H2O Io within limits |
| N/A | Moving variation in CO2 Io within limits |
| N/A | Moving variation in H2O Io within limits |
| N/A | CO2 signal level ok |
| N/A | H2O signal level ok |
| N/A | Gas head calibration signature ok |
| N/A | Heater control within limits |
| N/A | Differential pressure within limits |



Gas head lifetime hours not connected

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分析仪信号强度 vs 窗口清洁

- › 分析仪信号强度，实时动态补偿窗口变脏程度
- › 随着时间推移，分析仪窗口上的灰尘累积越来越多
- › 如果信号强度过低，分析仪读数可能不准确
- › 每次访问站点时，最好清洁一次分析仪窗口



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分析仪防雨网

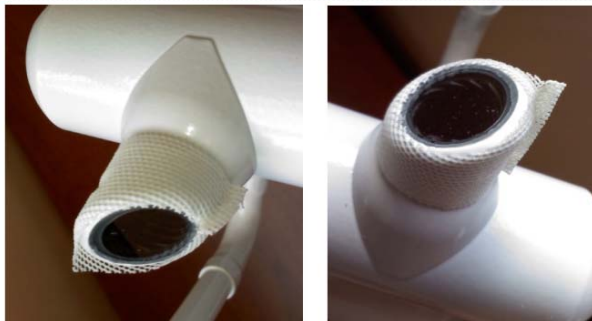
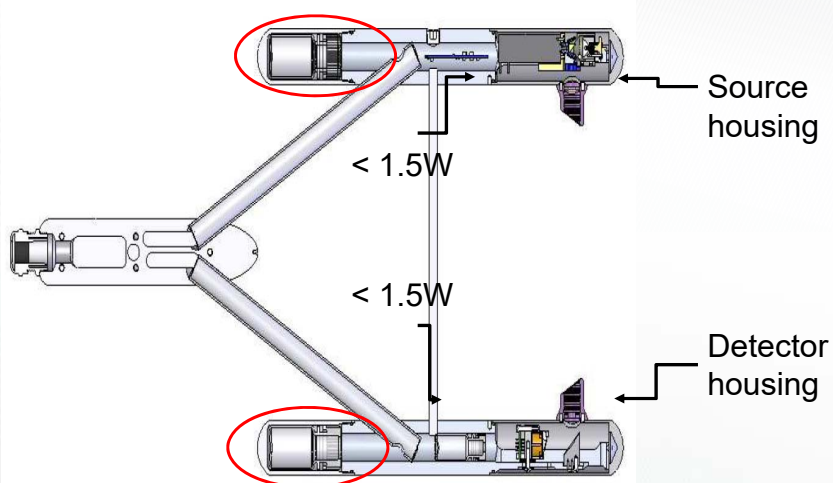


FIGURE 8-1. Proper location of the gas analyzer top wick (left) and bottom wick (right)

- › 定期更换
- › 低温冰冻区域, 可不使用
- › 多风沙地区, 可不使用



更换CO₂/H₂O吸收剂



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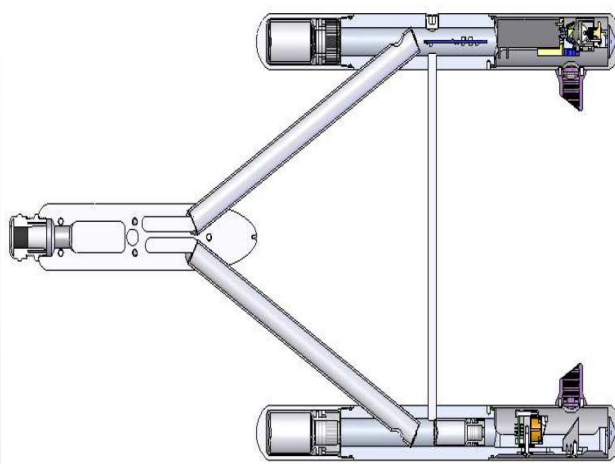
多长时间更换一次CO₂/H₂O吸收剂?

- › Campbell Scientific 建议每年更换一次
- › 不过, 如果zero 和span 系数发生较大漂移, 则应该及时的更换CO₂/H₂O吸收剂
- › 新的吸收剂成分是分子筛, **无毒无害**
- › 更换吸收剂后, 等待3天, 再实施Zero/Span



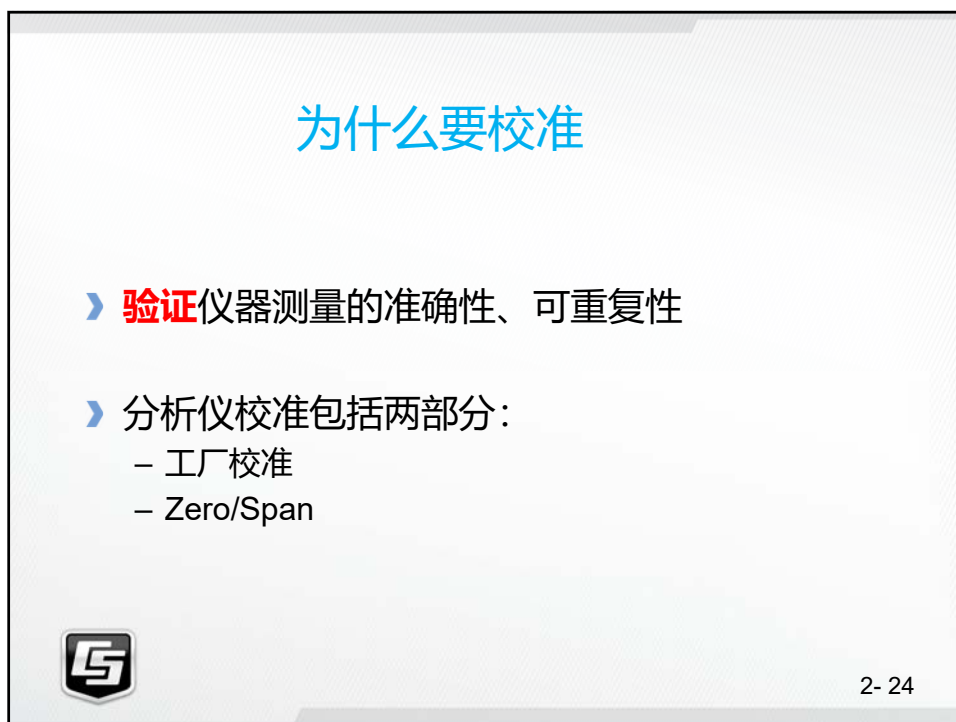
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- › 在更换吸收剂之前使用高纯N₂ 吹扫 分析仪是否是一种好的方式?

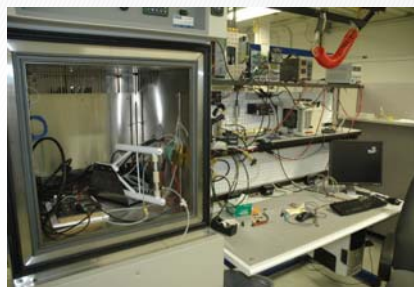


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气体分析仪工厂校准 —— 寻找分析仪的工作曲线



^ factory calibration (CO₂ concentrations, pressures, temperatures and dew points in combinations encountered in practice)

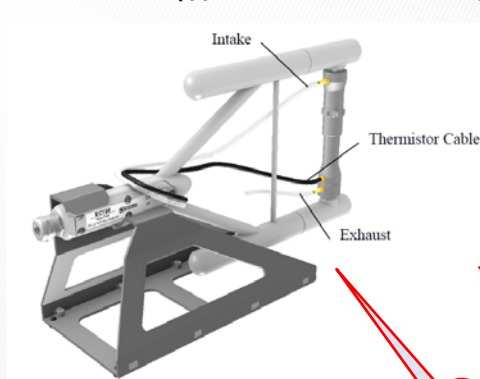
$$CO_2 = S_{CO_2} * f_{CO_2cal} \left\{ Z_{CO_2} * \left(\frac{CO_2 I}{CO_2 I_0} \right) \right\}$$

$$H_2O = S_{H_2O} * f_{H_2Ocal} \left\{ Z_{H_2O} * \left(\frac{H_2O I}{H_2O I_0} \right) \right\}$$



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ZERO 和 SPAN —— 进一步调整零点和跨度系数



^ 2点校准 (零气和跨度标气)

$$CO_2 = S_{CO_2} * f_{CO_2cal} \left\{ Z_{CO_2} * \left(\frac{CO_2 I}{CO_2 I_0} \right) \right\}$$

$$H_2O = S_{H_2O} * f_{H_2Ocal} \left\{ Z_{H_2O} * \left(\frac{H_2O I}{H_2O I_0} \right) \right\}$$



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很多因素都会影响分析仪的测量准确度 Accuracy

- › 温度变化 (环境温度和分析仪温度)
- › 交叉干扰度 (CO₂/H₂O)
- › 环境压力
- › 光路的清洁程度
- › 湿度
- › 内部化学吸收剂的有效性
- › 电子元件的老化



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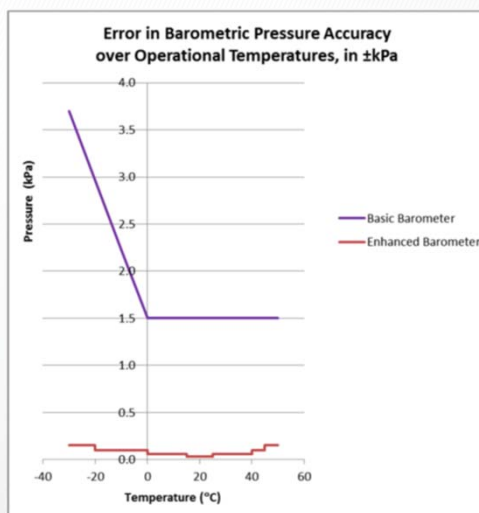
选择什么气压传感器?

- › 基本型BB 或 增强型EB?
 - 大气压P 用于计算空气密度, 1% 的气压误差会导致 1% 的显热通量误差。
 - 尽管CO₂ 跨度校准是以浓度单位输入, 但是需要大气压用于计算CO₂/H₂O的密度, 因此 1% 的气压误差会导致 1% 的CO₂通量误差。



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两种类型气压计的准确度Accuracy指标:



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校准备件:

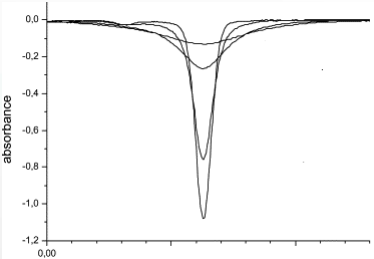

- ▶ 分析仪支架 —— PN 27278
- ▶ 光路气室 —— PN 26390
- ▶ 高压钢瓶减压器和流量计
- ▶ 铝塑管, 带Swagelok接头, 最好带三通 —— 21823-L20
- ▶ 零气发生器或高压零气, CO₂ Span 标气, H₂O Span (露点仪)
- ▶ 其它 —— 30厘米长活动扳手、BEV管、直流电源




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ZERO 和 CO2 SPAN

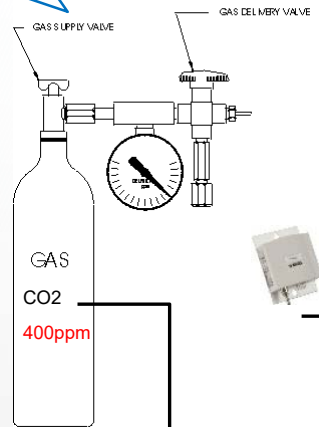
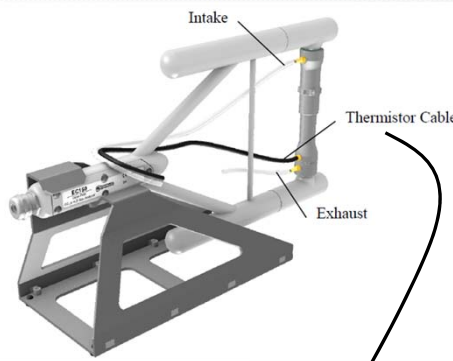
- ▲ 零气: 不含CO2的干空气 或 高纯N2
- ▲ Span 标气: 以干空气为平衡气的CO2标气 不含 其它杂质气体



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正确的操作顺序, 避免污染标气。

CO2 SPAN

$$\rho_c = \frac{X_c M_c}{10^6} \left(\frac{P}{R(T + 273.15)} \right)$$


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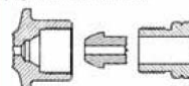
高质量的气瓶减压器



CYLINDER VALVE CONNECTIONS

CGA Connections

Connection 590
965-14NGO LH Int.

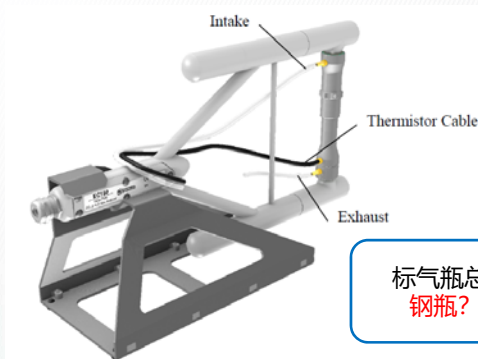


| Air (Industrial) | |
|------------------|------------------|
| Nut | 830 1215 |
| Gland | 830 4128 (2 1/2) |
| | 830 4123 (3) |
| | 830 3274 (3 1/2) |
| | 830 4122 (4) |

- ▲ Designed for use with ultra high purity gasses
- ▲ Clean
- ▲ Corrosion resistant materials
- ▲ Low internal volumes



ZERO 和 SPAN



标气瓶总开关
钢瓶? No!

- ▲ 2点校准 (零气和跨度标气)

$$CO_2 = S_{CO_2} * f_{CO_2cal} \left\{ Z_{CO_2} * \left(\frac{CO_2 I}{CO_2 I_0} \right) \right\}$$

$$H_2O = S_{H_2O} * f_{H_2Ocal} \left\{ Z_{H_2O} * \left(\frac{H_2O I}{H_2O I_0} \right) \right\}$$



CO2标气中的平衡气应该与大气成分比接近

$$A = \log(I/I_0) = \epsilon cL$$

$\epsilon = f(\text{gas composition})$

gas composition = 20.94% O₂ + 78.08% N₂ + 0.0004% CO₂

- ⤴ Use air as a balance gas, NOT nitrogen. The presence of oxygen changes the absorption coefficient
- ⤴ Low levels of other contaminants (CH₄, N₂O, etc.)
- ⤴ Check with NIST standards



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TYPES OF GAS MIXTURES

Air Liquide supplies a number of different grades of mixtures both in the gas and liquid phase. These different grades meet the requirements for most applications that standards are used for in laboratory and analytical applications.

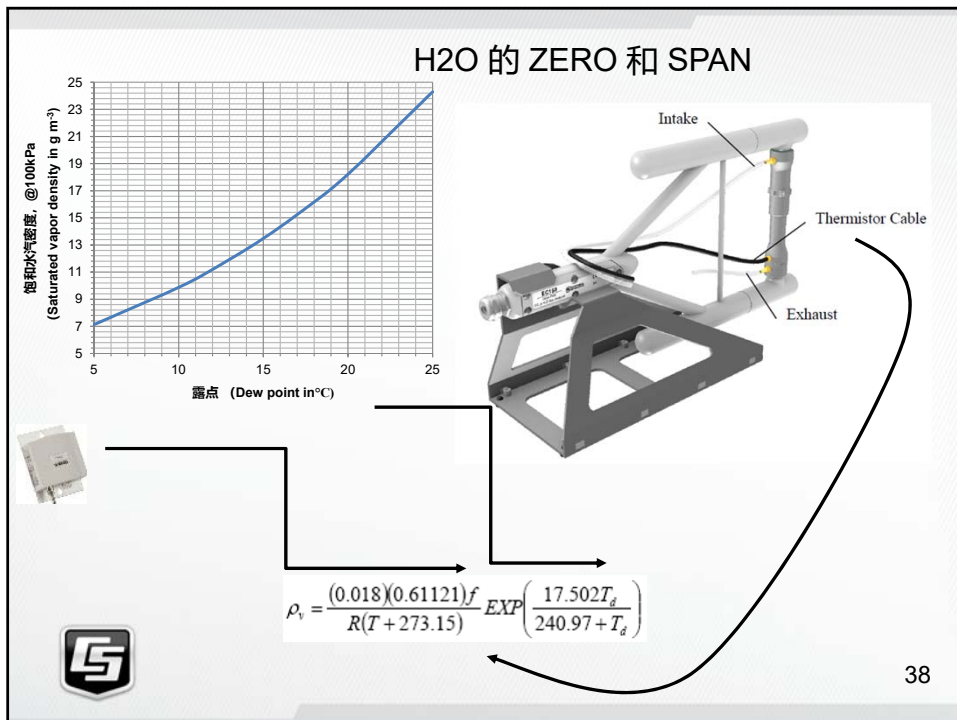
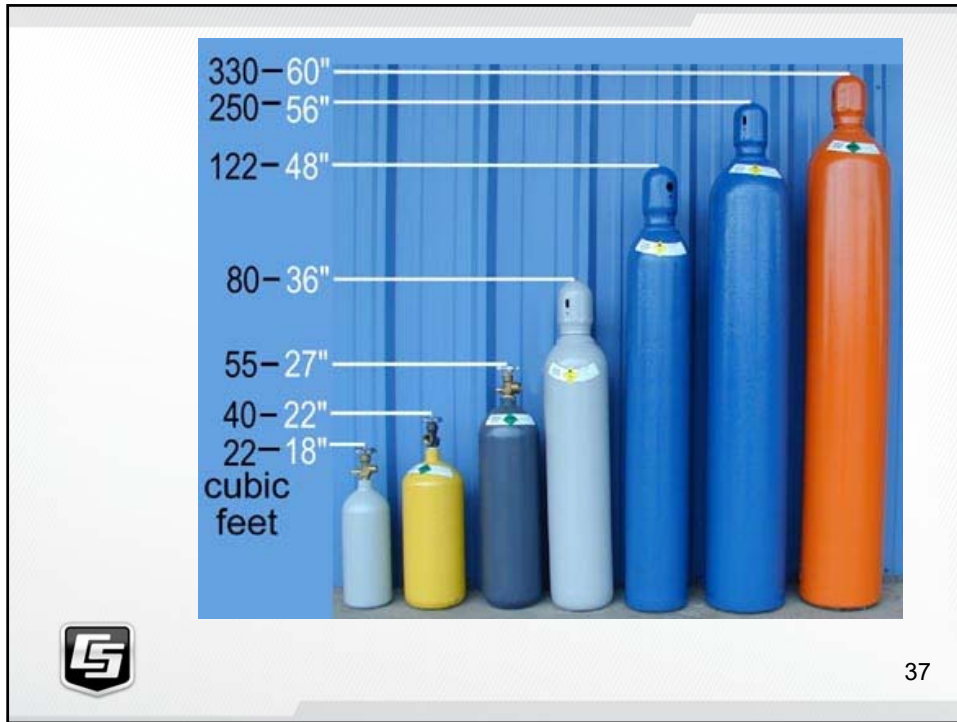
Dual Certified Primary Standards are recommended where the greatest accuracy is required. These mixtures are prepared gravimetrically to close tolerances and analyzed against NIST traceable standards. The reported concentrations are tied to both the gravimetric numbers and the analytical results to determine the reported uncertainty. Both numbers should fall within 1% of the reported value. Such dual analysis ensures the greatest accuracy.

Primary Standards are prepared gravimetrically to close tolerances. They are analyzed against reference standards if available to confirm the gravimetric numbers. The methodology used to determine each concentration and the uncertainty is reported on the Certificate of Analysis.

Custom Certified Standards are prepared gravimetrically but must be certified against traceable reference standards. Gravimetric numbers may be used in place of analytical numbers but only if they are determined to have less uncertainty. The method of determination of the reported number is stated on the Certificate of Analysis.

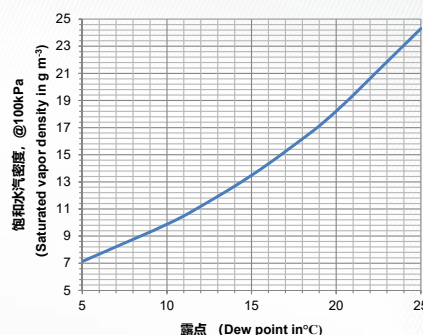


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提升露点精度

- › 流量不要过大
- › 订正露点发生器内部泵压产生的露点偏差



$$T_{d,GA} = \frac{240.97 \left(\ln \frac{P_{GA}}{P_{GA} + 0.097h} + \frac{17.502T_d}{240.97 + T_d} \right)}{17.502 - \left(\ln \frac{P_{GA}}{P_{GA} + 0.097h} + \frac{17.502T_d}{240.97 + T_d} \right)}$$



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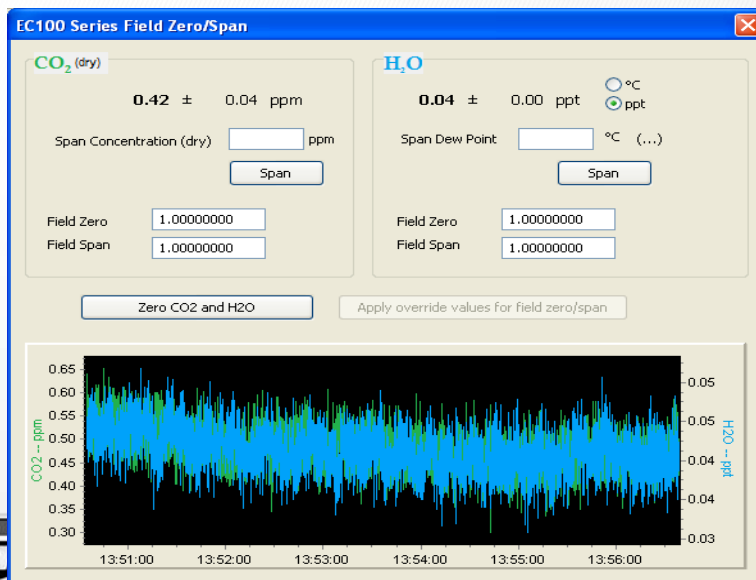
工作环境:

- › 远离日光直射、加热器、电风扇、空调出风口等不利于仪器稳定工作的环境。
- › 分析仪和露点发生器需要充分预热
- › 在校准之前, 先用无水乙醇或医用酒精 (75% vol/vol) 清洁分析仪窗口; 在操作中始终监视信号强度变化



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监视读数是否稳定：



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检查分析仪增益 (Gain)：

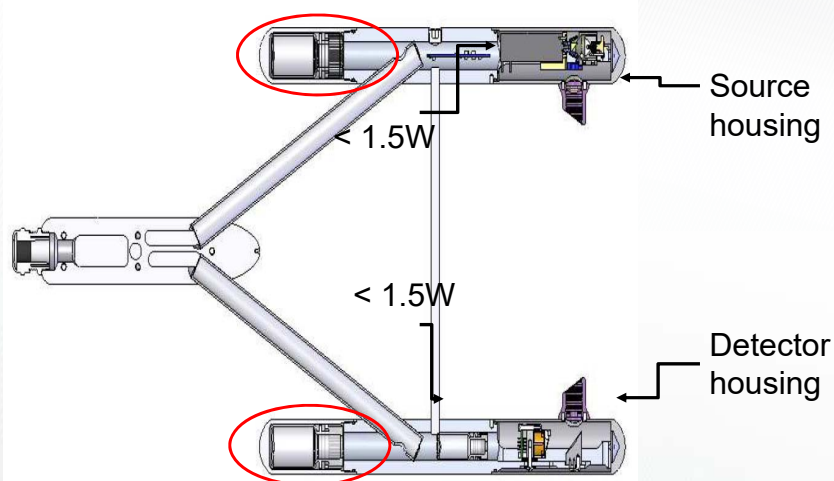
$$Gain = \frac{\text{标准CO}_2\text{浓度}}{\text{标准CO}_2\text{测定值} - \text{无CO}_2\text{测定值}}$$

- ▶ 如Gain=1，且无CO₂时气体分析的CO₂测定值为0，则无需进行CO₂的零点和跨度重置。
- ▶ 如Gain < 0.95 或Gain > 1.05，应检查CO₂吸收剂，并跟据吸收剂的已工作时间考虑更换。（若更换，等待3天）



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为什么要更换CO₂/H₂O吸收剂?



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多长时间更换一次吸收剂?

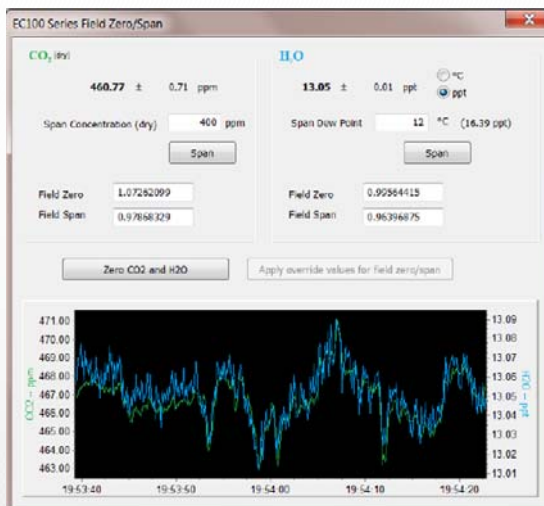
- › Campbell Scientific 建议每年更换一次
- › 不过, 如果zero 和span 系数发生较大漂移, 则应该及时更换CO₂/H₂O吸收剂
- › 新的吸收剂成分是分子筛, **无毒无害**

› 更换吸收剂后, 等待3天, 再实施Zero/Span



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- 在条件允许的情况下，Campbell Scientific 推荐用户在站点现场对分析仪进行Zero/Span校准。但站点现场的校准操作一般需要等待更长的时间让读数达到稳定。



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零气发生器

- 非常实用的一个工具
 - 用于对分析仪作零点校准
 - 方便携带



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校准顺序:

- › CO2/H2O Zero
- › CO2 Span
- › H2O Span



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| | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>CO₂ (dry)</p> <p>5.42 ± 0.00 ppm</p> <p>Span Concentration (dry) <input type="text"/> ppm</p> <p><input type="button" value="Span"/></p> <p>Field Zero <input type="text" value="0.99773550"/></p> <p>Field Span <input type="text" value="0.95979738"/></p> | <p>H₂O</p> <p>1.81 ± 0.12 ppt</p> <p>Span Dew Point <input type="text"/> °C (...)</p> <p><input type="button" value="Span"/></p> <p>Field Zero <input type="text" value="0.98468721"/></p> <p>Field Span <input type="text" value="0.98367810"/></p> |
| <p>CO₂ (dry)</p> <p>-0.04 ± 0.03 ppm</p> <p>Span Concentration (dry) <input type="text"/> ppm</p> <p><input type="button" value="Span"/></p> <p>Field Zero <input type="text" value="1.00005579"/></p> <p>Field Span <input type="text" value="0.95979738"/></p> | <p>H₂O</p> <p>-0.01 ± 0.00 ppt</p> <p>Span Dew Point <input type="text"/> °C (...)</p> <p><input type="button" value="Span"/></p> <p>Field Zero <input type="text" value="0.99547803"/></p> <p>Field Span <input type="text" value="0.98367810"/></p> |

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CO₂ (dry)
 970.58 ± 0.08 ppm
 Span Concentration (dry) [] ppm
 Span []
 Field Zero 1.00003123
 Field Span 0.95979738

H₂O
 -0.01 ± 0.00 ppt
 Span Dew Point [] °C (...)
 Span []
 Field Zero 0.99527359
 Field Span 0.98367810

Zero CO₂ and H₂O Apply override values for field zero/span

CO₂ (dry)
 1005.17 ± 0.03 ppm
 Span Concentration (dry) 1005.20 ppm
 Span []
 Field Zero 1.00003123
 Field Span 0.99400294

H₂O
 -0.05 ± 0.00 ppt
 Span Dew Point [] °C (...)
 Span []
 Field Zero 0.99527359
 Field Span 0.98367810

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Series Field Zero/Span

H₂O
 11.90 ± 0.00 ppt
 Span Dew Point 10.01 °C (12.40 ppt)
 Span []
 Field Zero 0.99527359
 Field Span 0.98367810

EC100 Series Field Zero/Span

CO₂ (dry)
 1442.81 ± 0.96 ppm
 Span Concentration (dry) 1005.20 ppm
 Span []
 Field Zero 1.00003123
 Field Span 0.99400294

H₂O
 12.40 ± 0.00 ppt
 Span Dew Point 10.01 °C
 Span []
 Field Zero 0.99527359
 Field Span 1.02394283

Zero CO₂ and H₂O Apply override values for field zero/span

14:24:30 14:25:00 14:25:30 14:26:00 14:26:30

14:24:30 14:25:00 14:25:30 14:26:00 14:26:30 14:27:00 14:27:30

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小结: Zero/Span 操作中 可能会碰到的一些问题

- › Zero/Span的操作顺序
- › 温度的影响因素
- › 压力的影响因素
- › 校准中读数大小对Zero/Span系数的影响
- › 水汽露点值大小的选取
- › 冬季的Zero/Span 校准
- › EC15x 分析仪在高原上的应用



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3. 开路分析仪 Zero/Span 操作演示

注意事项

- › 正确安装校准管 (IRGASon ***)
- › 露点仪充分预热



4. 闭路系统 Zero/Span 操作演示

CPEC310 自动在线校准



校准前注意事项

- › 防止过高压力危害系统安全
- › 正确安装
- › 漏气检测
- › 管路吹扫 (Purge)
- › 标气压力 (流速) 调节
- › 备份 Zero/Span 系数

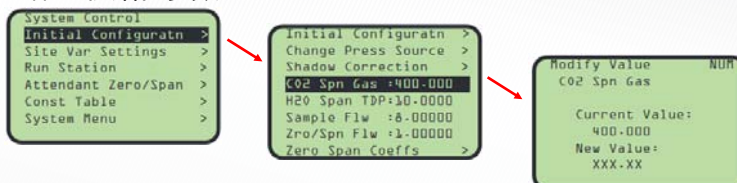
CPEC310 自动在线校准



- › 程序自动控制
- › 含 Valve Module
- › Scrub Module (默认) 提供零气, CO2 标气瓶提供CO2 Span 标气
- › 自动在线校准可实现 Zero All 和 Span CO2, 理论上也可以把Span H2O 包含在自动校准序列里

自动在线校准参数预设置

1. 配置初始化参数




2. 将自动校准选项设为真

```

Run Station :
Pump Tmpr 0k: True
Pump Tmpr : 30.0000
Pump flow : 8.00000
System diag : 0
Auto Z/S on : True
pump off : FLD_NEA
EC155 PV on : True
  
```

3. 配置常数(校准时长、校准间隔等), 并启动程序



```

NUMBR_HFP : 4
HFP_SNSTVT_1 : 62.0000
HFP_SNSTVT_2 : 62.0000
HFP_SNSTVT_3 : 62.0000
HFP_SNSTVT_4 : 62.0000
CAL_INTV : 1440
Apply and Restart
  
```

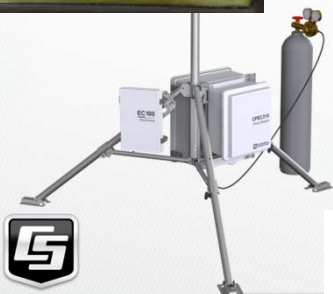
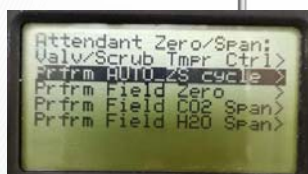


自动在线校准典型动作序列 (Check 和 Set)

| Site | Description | Duration | |
|--------|-------------|----------|---------|
| SITE_1 | fld smp | | 测量 |
| SITE_2 | offst P | 10 sec | 泵停止 |
| SITE_3 | chk CO2 | 65 sec | 检查CO2 |
| SITE_4 | chk zro | 85 sec | 检查 Zero |
| SITE_5 | set zro | 10 sec | 设定 Zero |
| SITE_6 | set CO2 | 90 sec | 设定 CO2 |
| SITE_7 | chk H2O | 185 sec | 检查 H2O |
| SITE_8 | set H2O | 10 sec | 设定 H2O |
| SITE_9 | Equilib | 30 sec | 平衡, 泵启动 |
| SITE_1 | fld smp | | 测量 |



CPEC310 现场校准



- › 操作者控制 数采菜单
- › 可实现:
 - Auto Zero/Span Cycle
 - Field Zero All
 - Field CO2 Span
 - Field H2O Span
- › 阀控动作系列与自动在线校准类似 (Check 和 Set)

通过LoggerNet 操作现场校准

| Mode | Abbreviation | Description |
|------|--------------|-------------|
| 1 | FLD_MEA | 测量模式 |
| 2 | PMP_OFF | 泵停止 |
| 3 | ZRO_ALL | 零点校准 |
| 4 | SPN_CO2 | CO2 跨度校准 |
| 5 | SPN_H2O | H2O 跨度校准 |
| 6 | IRG_SLP | 分析仪休眠 |
| 7 | AUTO_ZS | 零点/跨度 校准 |





注意事项

- › 根据系统要求，需要安装4到8套Sample Intake
- › 负压工作
- › 露点仪充分预热
- › Zero 和 CO2 Span 可实现自动在线校准
- › H2O Span 需要手动操作，需要准备三通，需要知道AmbientPressure 和 CellPressure
- › 管路吹扫 (Purge)



