The sample probe is a component of the process analyzer sample-conditioning system. It effects the removal of the sample stream from the process stream. The sample stream initially removed by the probe’s sample tube (often referred to as the “quill”) should accurately represent the process stream in all chemical composition aspects. Stated another way, the sample probe should accomplish sample stream removal without altering the representative chemical composition of the process stream.

A specific sampling methodology, referred to as “isokinetic” sampling, is utilized where one wishes to keep the sample “physically consistent.” This sampling methodology is defined by the relationship where the velocity of the sample extracted is equal to the velocity of the process sample stream. It requires laminar flow (flow parallel to the walls of the process line). It is most often utilized where there is a two-phase sample (particulate and gas, particulate and liquid, immiscible liquid and liquid, suspended liquid droplets in gas) and the analyst wishes to include the minor phase in the sample extracted for the analyzer. A particular probe design for this type of sampling is described in detail in ASTM D1066-6ST.

In some instances the design of the sample probe is specifically utilized to alter the physical composition of the sample stream (“non-isokinetic” sampling). There are times when you wish to use the design of the quill or the orientation of the quill to effect initial physical (inertial) separation of some component from the sample stream. Examples are removal of a solid particulate by inertial separation around the sample probe from a gaseous or liquid stream or liquids rejection in a gaseous sample by sample probe positioning.

There are other times when you wish to use the design of the quill to effect proper sampling across a wide duct where stratification of sample may take place. In this instance you use a quill that spans the duct, and it will have small openings (holes or orifices) equally spaced across the length of the quill (equivalent to the approximate span or diameter of the duct). As the sample is withdrawn from the duct into the sample probe quill, some sample is taken from each area of the duct and the total sample withdrawn is representative of the total composition across the duct.

Sample probes for simple extractive sampling systems can vary greatly in their details. The most basic probe is a quill welded through a blind flange; it is undesirable but cheap and effective—until it plugs! One step up is the probe that can be rodded out, which can only be used on a negative draft (usually stack) sample point or a process sample point where the process is not reactive with or sensitive to the atmospheric oxygen that would bleed in during the rodding operation. Another step upward in complexity is the removable quill probe with a vaporizing pressure regulator. This is typically utilized to maintain a sample in a gaseous phase when reducing the sample pressure due to remov-
ing it from a high-pressure process. Heat must be added to overcome the Joule–Thompson cooling due to the pressure reduction. The heat is most often in the form of an electric cartridge heater inserted into the pressure-reducing regulator body or a steam coil surrounding the regulator body. A final addition to the sample probe consideration is the addition of blowback to maintain probe flow through the initial process contact opening where particulate blockage would be most likely to occur. Again due to the Joule–Thompson cooling effect, it is strongly recommended that the blowback gas be available in multiple liter per minute quantities at an elevated temperature (a heated accumulator assembly) approaching the temperature of the process being sampled. This will preclude the pressure reduction of the blowback pressure release, which can cause the blowback gas to fall below its dewpoint and add moisture to any particulate matter present in the process sample stream. The result will be mud. The mud will immediately plate itself out on the heated surfaces inside the sample probe assembly and exacerbate the very problem that you are attempting to alleviate with the heated blowback system!

Reliable suppliers of basic sample probes are:

ABB Automation Inc. (HQ) Lewisburg, WV 24901
(formerly Hartmann & Braun)
Buhler Analysis Systems Inc. Frankfort, IL 60423
M & C Products- USA Newbury Park, CA 91320

Two reliable suppliers of ceramic probes are:

Bolt Technical Ceramics Conroe, TX 77305
Vesuvius McDanel Co. Beaver Falls, PA 15010

Very hot streams may be sampled using a water-jacketed (see ABB Automation Inc., formerly Hartmann & Braun, probe model 60 below) or water-washed probe assembly. Temperature reductions of more than a thousand degrees can be achieved in the first several inches of a water-washed or water-jacketed probe, depending on the sample flow rate. Excess water flow that is not consumed by the probe assembly is to be avoided. This prevents damage to process metallurgy or ceramics downstream of the water-wash by differential cooling. A water-washed probe requires separation of the water from the sample gas downstream in the sample conditioning system. A water-washed system also requires that the gas not be significantly soluble in the water at the temperature of the wash or that the solubility of the gas at these temperatures be known. A third consideration is to saturate the water with the gas prior to the water-wash operation. A water-washed probe is also a good means for removing particulate from gaseous sample streams.

Sample probes that effect sample dilution are another type of sample probe. These probes dilute the sample gas with clean dry air (often at a 100:1 ratio) to a lower concentration that generally precludes moisture condensation (dewpoint) problems as well as effecting adjustment of the sample concentration to suit certain analyzer (generally laboratory ppm and ppb) measuring ranges. This dilution is effected utilizing an air-aspirated dilution eductor with a critical orifice (e.g., laser drilled synthetic ruby). The dilution can be on a wet basis or a dry basis measurement. The question of a wet or dry basis measurement is not trivial, and the answer to use is not straightforward. The answer depends on how the flue gas emissions are to be reported, and this affects the total design of the analyzer system (often referred to as a Continuous Emissions Monitoring System CEMS). Dry basis measurement requires a portion of the sample be routed to a process oxygen analyzer to provide an undiluted oxygen measurement. However, if the analytical measurement is made on a dry basis and the mass flow of the pollutants must be reported, the moisture content must be known, since the mass flow measurement in the stack gas is made on a wet basis concentration value.

Two suppliers of dilution probes are:

EPM Environmental Mt. Prospect, IL 60056 FON: 847.255.4494
STI Waldron, AR 72958 FON: 501.637.4152

Two reliable suppliers of FTIR, NIR, mid-IR, and UV-VIS systems utilizing stainless-steel-sheathed fiber-optic cable that can be directly inserted into the process via a compression fitting or a Conax gland fitting (see Packing Gland in Exhibit 1.1a).

Reliable manufacturers of these probes are:
Sample probe length in pipes or ducts should find the sample probe one meter in length or the end of the sample probe should be in the middle third (30–70%) of the duct or pipe diameter, whichever is the smaller measurement. In either case you want the sample probe tip to be in an area of turbulent flow or in an area where the sample is representative of the sample composition of the entire pipe or duct.

The sample probe is designed to be either cleaned in place safely or safely removed from a pressurized pipe or duct. A sample probe that can be cleaned in place safely typically is straight so that a rod can be passed through it from sample exit back to sample source. During cleaning, the pipe or duct must be at a negative pressure and the process must not react with atmospheric oxygen (which would be sucked into the pipe or duct as the sample probe is cleaned). To be removed safely from a pressurized pipe or duct, the sample probe must pass through a gland fitting that can hold the process pressure without leakage yet allow movement of the sample probe, again without significant leakage of the process material (especially if the process material is toxic).

A reliable manufacturer of these gland fittings is:

Conax Buffalo Buffalo, NY 14225
FON: 716.684.4500
Technologies

The A+ Corporation in Prairieville, LA 70769 (FON: 225.622.6731) has developed a “membrane-protected” probe that can be inserted and retracted via a \( \frac{3}{4} \)-in. Thread-O-Let into a process pipe at pressures up to 2000 psig/13,790 kpag. Insertion of this probe into the Thread-O-Let opens a “foot” valve located in the lower probe housing. Gas from the process can flow freely through the membrane, but it will reject all liquids at process line temperature and pressure. The liquid will drain back into the process pipe by gravity. The membrane-protected probe avoids changes in gas sample composition brought about by liquids being drawn into the probe and vaporizing later in the sample conditioning system, causing gas sample composition “spikes.”

ABB Automation Inc. (HQ) in Lewisburg, WV 24901 (FON: 304.647.4358), formerly Hartmann & Braun, has several commercially available standard probes. The more simple are the two probes (models 2 and 40) having a filter internal to a cylindrical probe head (model PFE2) that resides just outside of the process pipe. This probe head can be heated by a multi-wattage ring-heater that wraps around the probe head. The probe head then can easily be placed in an insulated enclosure to effect a heated sample probe system. As detailed above, high-pressure blowback capacity tanks and their valves can also be added within this insulated enclosure to effect a proper heated blowback system. The more specialized probe is the probe model 60, which is specific for sampling and filtering very hot and heavily particulate-laden steel and cement process sample gases. This probe has a water-jacket surrounding the probe quill, and its sample inlets are at the sides of the quill (to allow much of the particulate matter to pass over the probe and not be taken in with the sample gas). It has a heated sample filter with heated compressed air blowback. This probe requires a closed-circuit cooling water system. The application parameters for this probe are process pressure up to 29 psig/2 barg, process temperature up to 2372°F/1300°C, and a dust content of up to 2000 g per cubic meter. Due to the weight of this water-jacketed probe, it has a probe retraction system that can be either manual (consisting of a support frame and carriage/movement unit that is activated by a geared handwheel) or automatic (having a motorized movement controlled by electrical signals).

Other suppliers of heated process sample probes with external-access filter and optional blowback (backpurge) are:

Fisher-Rosemount, Orrville, OH 44667
Analytical-Process Analytic Division

Buhler Analysis Systems Inc. Frankfort, IL 60423
FON: 815.464.8715
Figure 1.1a Basic liquid sample probe. Gas sample probe would be $\frac{1}{2}$ in. OD $\times$ 0.035 in. wall tubing.

Figure 1.1b Basic liquid sample probe. Reprinted, with permission, from Siemens Applied Automation Inc.
FFA Pickup Tube Options - Build complete pickup tube assembly starting with LMIP1 injection piece

FFA complete pickup tube assembly shown below is simple open ended type - see lower drawing for pickup with holes

injection piece for spangas
also called
spangas attachment

3/8” OD SS pickup tube open or closed end types offered

bulkhead plate welded to indexing tube

1’, 2’, 3’ or 4’

locking plate

3/8” SS tube part of pickup tube

locking plate welded to open or closed pickup tube

LMBP1

bulkhead plate with stud to accept pickup tube locking plate

is 4” square with mounting holes 3” by 3” square

5 holes - #50 size & closed end

7/16”20 by 1/2” in. long SS socket set screw in threaded end

locking plate with clearance hole for stud is 1.25” by 2.25”
makes complete tube assembly when welded to pickup tube and injection piece, attaches to bulkhead by stud wingnut

Figure 1.1c  Atmospheric pressure sampling probes which can span the duct or stack. Note long probe end support plate (LMBP1) and duct area sample averaging probe (LMBLP). Reprinted, with permission, from L & M Technical Services-SAFESTARTS® NATIONAL equipment.
Figure 1.2  Liquid sample probe with explosion-proof electric-heated vaporizing pressure regulator. Overpressure relief valve is to left of pressure gauge face. Transfer line (¾ in. tubing) to be installed from probe valve to inlet of tee filter screwed into heated vaporizing pressure regulator. Line is attached to probe quill in front of probe valve with two black cable tie wraps. Reprinted, with permission, from Siemens Applied Automation Inc.
Figure 1.3  Liquid sample probe with explosion-proof electric-heated vaporizing pressure regulator with all sample transfer lines installed. Reprinted, with permission, from Siemens Applied Automation Inc.

Figure 1.4a  Heated sample probe with heated blowback system. Note 2 x 2L blowback gas capacity tanks to provide immediate high-pressure heated blowback gas volume upon opening electropneumatic solenoid valve (SV7) which is plumbed with 3/8 in. tubing for high volumetric flow rate.
**Figure 1.4b** Heated sample probe with heated blowback system. Mounted on repair stand. View is essentially along axis of process sample probe. Note the two tubes going into uplifted probe protection box lid to the $2 \times 2L$ blowback gas capacity tanks.

**Figure 1.4c** Heated sample probe with heated blowback system. Mounted on repair stand. Note $2 \times 2L$ blowback gas capacity tanks mounted to either sidewall of uplifted lid assembly.
Figure 1.4d  Heated sample probe with heated blowback system. Note compact overall size, simple filter element, removable carrier, and integral heat-traced and insulated sample transfer line strain-relief boot exiting filter protection box bottom. Reprinted, with permission, from Baldwin Environmental Inc.
**Figure 1.5** Backflushing a sample probe with connection details illustrated and a recommended pulsed pressure program (continued on next page) for 1-stage backflushing of filter surface and pipe (probe/filter housing). Reprinted, with permission, from ABB Automation Products Hartmann + Braun Division.
1. Start cleaning
2. End cleaning
3. Cleaning cycle
4. Pilot valve/diaphragm valve -Y3.1/Y3.2 cleaning filter surface and pipe
   o Open
   c Closed

Figure 1.5  Continued.

Figure 1.6  Backflushing a sample probe with connection details illustrated* and a recommended pulsed pressure program* for 2-stage backflushing of both filter surface and pipe (probe/filter housing) and through filter element (inside to outside). Reprinted, with permission, from ABB Automation Products Hartmann + Braun Division. (*continued on next page).
5 Pilot valve -Y2.1 cleaning filter
6 Diaphragm valve -Y2.2 cleaning filter
7 C Non-return valve sample gas connection -Y5
   (installed in the clamping ring threaded joint)
8 Pilot valve -Y1.1 pulsed compressed air
9 Diaphragm valve -Y1.2 pulsed compressed air
10 Control air 2...6 bar
11 Compressed air backflushing 4...6 bar
12 Sample gas pipe
15 Solenoid valve -Y4 venting
16 Diaphragm valve -Y3.2 cleaning filter surface and pipe
17 Pilot valve -Y3.1 cleaning filter surface and pipe

1 Start cleaning
2 End cleaning
3 Cleaning cycle
5 -Y1.1/Y1.2: Pulsed compressed air
6 -Y4: Venting
7 -Y2.1/Y2.2: Cleaning filter
8 -Y3.1/Y3.2: Cleaning filter surface and pipe
o Open
c Closed

Figure 1.6 Continued.
Figure 1.7  Simple quill probe with integrally electric-heated and insulated probe body filter element. Filter is removed via black tee-handle. Filter body has integral low-temperature alarm contact. Reprinted, with permission, from Buhler Analysis Systems Inc.

Figure 1.8  Two APO-series sample probes. One with sintered stainless steel filter over probe quill and blowback tube connection on probe body. One with high-volume probe tip blowback setup using flanged connections. Reprinted, with permission, from Buhler Analysis Systems Inc.
- Easily adaptable to different sampling conditions thanks to modular construction
- Components:
  - FE2 / PFE2 filter unit and
  - probe tube types 2, 40, 40 coated, 42, 60, K
- Probe tubes, filter unit and sample gas connection heatable
- Connections for test gas and purging
- Filter with high retention rate and long service life
- Easy filter replacement
- Advance Optima system solution for communicating with the analysis system (in preparation)
- Usable in emission measuring devices conforming to 13. BlmSchV and 17. BlmSchV (Federal Immission Protection Law)

**Figure 1.9a** Modular sample gas probe system (ES1). Mix-and-match components including probe tube types (6 selections), filter unit heaters(2), and probe housing(1). Reprinted, with permission, from ABB Automation Products Hartmann + Braun Division (*continued on following pages*).
Probe housing, PFE2 filter unit terminal diagram, terminal block X3

Probe housing Terminal box, strip -X3

Pilot valve -Y2.1 filter cleaning
Extended cleaning
Pilot valve -Y3.1 cleaning of filter surface and tube
Pilot valve -Y1.1
Pilot valve -Y4
Probes / flange

Internal temp.
aprox. 100 °C
Use heat-resistant cable

Remove with equipotential bonding

230 V 50-60 Hz or
115 V 50-60 Hz

Dimensional diagram: Fitting of probe housing with PFE2 filter unit (dimensions in mm)

Flange DN 65 PN 6
DIN 2573
Type B

Figure 1.9a Continued.
Probe housing (dimensions in mm)

**Probe housing**

for gas sampling probes made of special steel 1.4301 with terminal box with degree of protection IP55

**View "A" (from rear)**

- Elongated holes M8 safety collar bolts
- Flange plate with pipe clamp 2.5 inch RST 37-2 hot galvanised DIN 3568

**View "B" (from below)**

- Terminal box made of special steel 1.4301 with holes for cable glands made up as required
  - 2x Pg21
  - 3x Pg16
  - 1x Pg13,5
  - 1x Pg11

Figure 1.9a  Continued.
**Regulated heating sleeve for filter unit FE2**

- **Heating**
  - micanite

- **Steady-state temperature**
  - max. 350 °C

- **Temperature control**
  - max. 200 °C Pt 100

- **Power supply**
  - 230 V AC, optionally 115 V AC

- **Output**
  - 250 W

- **Connection**
  - terminal box with CT bolted connection, protection level IP 54

- **Supply cable (1 m)**
  - 3 x 1 mm² with silicone sheath
  - ambient temperature: −20...+45 °C

- **Relative humidity**
  - ≤ 75 % yearly mean; infrequent slight condensation permissible

- **Weight**
  - approx. 1 kg

**CE-conformity**

The device conforms to EMC protection requirements and the low-voltage directive. It carries the CE mark.

**Essential accessories**

- Insulating sleeve
- D3 temperature controller

---

*Figure 1.9a Continued.*
Annular heating element

For heating the FE2 filter unit, which is a component of the modular gas sampling probe system.

Heating is necessary if condensation is likely from moist gases and there is consequently risk of the filter becoming clogged and corroded.

Data

Power supply
- 220 V, 50...60 Hz
- 110 V, 50...60 Hz

Heat output
- 200 W, 100 W or 50 W – depending on setting
- The heating resistors are factory-set for heat output of 100 W.

Temperature of heater
- approx. 120 °C to 180 °C (measured at ambient temperature of 20 °C, still air)

Ambient temperature
- 0 ... 55 °C (still air)

Protection provided by casing
- IP 50 to DIN 40050

Materials
- casing: aluminium alloy
- heating surface: brass

Weight
- approx. 0.4 kg

Electrical connections
- terminals via cable gland CT 13.5
- The electrical supply conductor must be heat resistant (≥ 200 °C).

Installation

The two half shells are placed round the FE2 filter unit to be heated and closed with a wing screw.

Figure 1.9a Continued.
Use

The filter unit is a component of the modular gas sampling probe system. It is for filtering gases containing dust.

Sampling conditions

Pressure
\[ P_{\text{max}} = 50\ldots600 \text{ kPa} \]

Temperature
\[ \text{max. } 200 \, ^\circ\text{C}, (\text{coated } 180 \, ^\circ\text{C}) \]

Flow rate
\[ 30\ldots500 \text{ l/h, relative to } 100 \text{ kPa and } 0 \, ^\circ\text{C} \]

Pressure drop
\[ \text{approx. } 10 \text{ hPa} \]

Dust content
\[ \text{max. } 40 \text{ g/m}^3, \text{ with type } 60 \text{ probe tube max. } 2,000 \text{ g/m}^3 \]
\[ \text{with blowback unit max. } 1,000 \text{ g/m}^3 \]

Retention rate
\[ 99.99 \% \text{ for particles } > 5 \mu\text{m} \]

Seal integrity
\[ 10^{-5} \text{ hPa l/s} \]

Materials of the gas-carrying parts

Casing and connections
special steel Mat. No. 1.4571

Flange
carbon steel (optionally special steel Mat. No. 1.4571)

Filter
aluminium-oxide surface filter

Mounting

Flange
DN 65, Form B to DIN 2573, flange gasket A;
positioning of holes
0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°, 360°

Mounting
Flange connect or bolt to the selected type of probe tube

Connection ports

Sample gas/test gas
G 1/4 internal thread to DIN ISO 228/1

Compressed air (2 ports)
G 1/2 internal thread to DIN ISO 228/1

Probe tube
G 3/4 internal thread to DIN ISO 228/1

Weight
approx. 8.0 kg

Compressed air supply for blowback
(see filter unit PFE2)

Instrument air
free of dust, water and oil

Pressure
max. 600 kPa

Figure 1.9a  Continued.
### Table 1.9b: Mechanical and Electrical Properties of Varied Ceramic Materials

<table>
<thead>
<tr>
<th>Property/Materials</th>
<th>Uniaxial Compression</th>
<th>Physical Strength</th>
<th>Thermal Properties</th>
<th>Dielectric Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cordierite</strong></td>
<td>U-0.4</td>
<td>15</td>
<td>6.0</td>
<td>750</td>
</tr>
<tr>
<td><strong>Lava</strong></td>
<td>L-0.4</td>
<td>20</td>
<td>8.0</td>
<td>1500</td>
</tr>
<tr>
<td><strong>Mullite</strong></td>
<td>M-0.4</td>
<td>10</td>
<td>9.0</td>
<td>3000</td>
</tr>
<tr>
<td>** Dense Alumina**</td>
<td>D-0.4</td>
<td>15</td>
<td>10.0</td>
<td>5000</td>
</tr>
<tr>
<td>** Dense Zirconia**</td>
<td>Z-0.4</td>
<td>20</td>
<td>11.0</td>
<td>1000</td>
</tr>
</tbody>
</table>

---

**Table Notes:**
- **Cordierite** is used primarily when steam environments exist.
- **Lava** is used as a prototype material for high-frequency, welding, and automotive applications.
- **Mullite** is used in refractory applications.
- **Dense Alumina** is used for high-temperature applications.
- **Dense Zirconia** is used for high-temperature applications.
- **Flexural Strength Under Room Conditions** varies across materials.
- **Density** and **Specific Gravity** data are provided for each material.

---

**Figure 1.9b:** Mechanical and electrical properties of varied ceramic materials used in process analyzer sample probes. Reprinted, with permission, from Superior Technical Ceramics Corporation.
Figure 1.10 Dilution probe stack sampler. Probe has an internal orifice that is selected to provide the desired dilution of the process sample below its dewpoint for nonheated sample transport and measurement by ambient air analysis level analyzers. Reprinted, with permission, from EPM Environmental Inc (continued on following pages).
MODEL 797

DILUTING STACK SAMPLER
TECHNICAL SPECIFICATIONS AND ORDERING INFORMATION

MODEL 797.302 DILUTING STACK PROBE
Special corrosion resistant nickel alloy material. Furnished with bolted support flange 46 mm (1 7/8”) diameter and 4 threaded mounting holes. Maximum temperature 400 degrees Celsius (752 degrees Fahrenheit). Probe length 310 mm (12 1/5”), diameter 27mm (1 1/12”).

MODEL 797.303
Same as above, but furnished with 7/8” G threaded end. To be used with a weld adapter to allow extension of probe to any desired length.

MODEL 797.302 C
Same as 797.302, but coated with HALAR®. Is used in very wet and corrosive environments. HALAR® is a fluoropolymer which prevents pitting of the material. Maximum temperature 180 degrees Celsius (320 degrees Fahrenheit).

MODEL 797.303 C
Same as 797.303, coated with HALAR® and threaded end piece.

MODEL 797.305
Same as 797.302, but for high temperature applications. Maximum temperature 600 degrees Celsius (1112 degrees Fahrenheit). Requires Quartz orifice with ball-joint mounting end.

MODEL 797.306
Same as 797.303, but for high temperature applications. See 797.305.

CRITICAL ORIFICES

<table>
<thead>
<tr>
<th>Nominal Flow m/min</th>
<th>Dilution Ratio</th>
<th>Glass</th>
<th>Quartz</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>215.1</td>
<td>350.1</td>
<td>2126.044 N/A</td>
</tr>
<tr>
<td>50</td>
<td>95.1</td>
<td>192.1</td>
<td>2126.047 N/A</td>
</tr>
<tr>
<td>100</td>
<td>44.1</td>
<td>75.1</td>
<td>2126.044 2126.057</td>
</tr>
<tr>
<td>150</td>
<td>32.1</td>
<td>50.1</td>
<td>2126.045 2126.058</td>
</tr>
<tr>
<td>200</td>
<td>27.1</td>
<td>37.1</td>
<td>2126.046 2126.059</td>
</tr>
<tr>
<td>250</td>
<td>20.1</td>
<td>30.1</td>
<td>2126.048 2126.060</td>
</tr>
<tr>
<td>500</td>
<td>12.1</td>
<td>16.1</td>
<td>2126.049 2126.061</td>
</tr>
</tbody>
</table>

HALAR® is a registered trademark of Allied Corporation.

CONTROL PANEL 797.440
Modular 19” panel for control of the pressurized air in the probe (all models). Flow meters allow the measurement and control of ”blow back air” for coarse filter cleaning and the flow adjustment of span gas. Height 8 3/4” = 5 units.

CONTROL PANEL 797.441
Same as model 797.440, but provides automatic blow back for cleaning of coarse filter.

DILUTER PANEL 797.430
Modular 19” panel to provide additional dilution step by cascading it to the probe or to provide accurate dilution capability in a bench top situation. Dilution rate is variable by changing the dilution air flow in combination with the selected critical orifice. Requires special critical orifices!

UMBILICAL CORD
Connects probe to control panel. Consists of 4 1/4” lines, strain relief cord and flexible mantle. Maximum recommended length 300 feet.

WELDING ADAPTER
For use on probes with 7/8” G threaded ends. Allows extension of probe to any desired length with appropriate extension pipe.

0040.260 Standard welding adapter for use with 1 1/4”, schedule 10 seamless SS pipe.
0040.261 As above, but for 1 1/4”, schedule 40 seamless SS pipe.
0040.262 As above, but for 1 1/4”, schedule 80 seamless SS pipe.
0040.263 As above, but for 1 1/2”, schedule 160 seamless SS pipe.

Figure 1.10 Continued.
Principle of Operation

The EPM Dilution Probe performs four critical functions to prepare the sample from the stack and permit precise and accurate measurement by the analyzer. It operates as follows (Figure 2):

Three to ten liters of clean, pressurized dilution air (1) is blown through the sharp nozzle (2) of the ejector pump (air driven aspirator) into the venturi (4). A built-in heat exchanger (7) preheats the pressurized air to the stack temperature.

The flow of pressurized air through the nozzle (2) creates a partial vacuum within the chamber (3), which is also connected to the low pressure end of the critical orifice (11). The vacuum, in turn, extracts a constant flow of sample from the stack (8), through the coarse (9), and depth (10) filters, and to the venturi outlet (5), where it is diluted and mixed with the clean, pressurized air. The diluted sample is then transported at positive pressure to the analyzer(s) via the unheated outlet line (6) in the umbilical cord.

Theoretically, critical flow for air occurs when the ratio of the absolute pressure at the chamber outlet (3) to the absolute pressure at the inlet (stack) is less than or equal to 0.53 bar (8.3 PSI). In order to maintain a constant flow rate through the critical orifice (and keep the orifice functioning within its critical range), the partial vacuum is kept at a gauge pressure below 0.47 bar (7.38 PSI). This vacuum is measured via a gauge (13) located on the system’s control panel (connected to the probe via one (13) of the four lines the umbilical cord.

Calibration gas is supplied to the probe via a separate line (12) in the umbilical cord. Because this line ends in the front compartment of the probe assembly, it ensures that calibration gas is supplied at the same location and under the same temperature and pressure conditions at which stack sampling takes place. This line is also used to measure the pressure within the stack and supply blow-back air to clean the coarse filter (9).

Figure 2

Figure 1.10  Continued.
Dilution Module for Analyzer Enhancement

Introduction

EPM Environmental is a major supplier of in-situ and out-of-stack dilution systems. During the last 10 years, well over 2000 EPM systems have been installed worldwide...and continue to provide reliable, 24 hour a day, 365 day a year operation in some of the most severe applications imaginable.

In fact, the reliability and dependability of our systems is such that 80% of the monitoring installations made in conjunction with the Acid Rain Program of the Clean Air Act rely on EPM dilution systems to deliver accurate samples. Moreover, as a result of this industry-wide acceptance and success, many analyzer manufacturers have also expressed an interest in the use of EPM dilution technology to enhance their range of analysis.

The EPM Environmental Dilution Module is designed to meet that need. Here are some of its key advantages:

- Compact design — can be built into most analyzers.
- Extremely small sample volume.
- Permits the use of low range analyzers and monitors to measure highly concentrated streams; dilution ratios up to 122,500:1 can be achieved when modules are used in series.
- Reduces the corrosive effects of harsh samples, reducing maintenance and prolonging analyzer life.
- Permits monitoring in hazardous areas by diluting sample to levels below the Lower Explosive Limit (LEL).
- Installation flexibility — can be mounted in a heated enclosure to prevent sample condensation.

Principle of Operation

The Model 797.311 Dilution Module is designed to provide dilution ratios from 1:10 to 1:350. The degree of dilution achieved is determined by the system’s critical orifice, the selection of which is based on the concentration of the sample and the measuring range of the analyzer. Seven different pre-calibrated critical orifices are available.

As shown below, clean air is applied to the dilution air inlet (1) at a pressure of about 40 PSI, driving a high efficiency air aspirator (2). The vacuum generated by the air aspirator pulls sample from the source and through a critical orifice (4) at a ultra-stable flow rate (for example, 500 ml/minute). Once the sample is pulled through the critical orifice, it is mixed with the clean air from the aspirator and presented to the analyzer (5) for measurement.

The actual dilution ratio is calculated as follows:
Dilution air flow rate at 1 = Q1; Sample flow rate at 4 = Q2
Dilution Ratio = Q1 + Q2 divided by Q2

Another method of determining the dilution ratio is by applying a calibration gas upstream of the critical orifice (4) and measuring the diluted concentration at the analyzer (5). The quotient is the dilution ratio.

Figure 1.10  Continued.
Figure 1.11a Insertion-type spectroscopic process analyzer sample probes and a flow-thru gas-phase sample cell. Reprinted, with permission, from Orbital Sciences Corporation-Applied Instrument Technologies.
Figure 1.11b  A 1 in. OD transmission (sample gap) probe for converting process spectroscopic measurements to optical signals for fiber optic transmission of process composition data. Reprinted, with permission, from Axiom Analytical Incorporated.
Figure 1.12  A 2.375 in. OD transmission (sample gap) probe for converting process spectroscopic measurements to optical signals for fiber optic transmission of process composition data. Note discrete light-guide tubes (detail key 4) as opposed to machined light-guide tubes in Fig. 1.11b probe. Reprinted, with permission, from Axiom Analytical Incorporated.
Figure 1.13 Genie probe regulator (GPR) installation schematic into process pipe. Reprinted, with permission, from A+ Corporation.

Figure 1.14 Genie probe regulator (GPR) installation detail into process pipe. Reprinted, with permission, from A+ Corporation.
Figure 1.15  Genie probe regulator (GPR) cutaway detail for internal operating illustration. Reprinted, with permission, from A+ Corporation.

Figure 1.16  Genie probe regulator (GPR) dimensional drawings of several available configurations. Reprinted, with permission, from A+ Corporation.
<table>
<thead>
<tr>
<th>For use in</th>
<th>Furnaces</th>
<th>Flue gas desulphurisation</th>
<th>Metallurgical industry</th>
<th>Cement and lime production</th>
<th>Ceramics industry</th>
<th>Glass industry</th>
<th>Coal breaking plants</th>
<th>Silo monitoring</th>
<th>Characteristics</th>
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</table>

1) coated  
2) if regularly cleaned with compressed air  
3) with restrictions  
4) observe official installation & operating regulations

**Figure 1.17** Probe-tube-type selection table with industrial applications and probe physical characteristics detailed. Reprinted, with permission, from Siemens Applied Automation Inc. (continued on following pages).
Use
For sampling hot dust-containing gases in conjunction with the FE2/PFE2 filter unit.

Process gas sampling conditions
Pressure
$p_{\text{abs}} = 50...500 \text{ kPa (0.5 ... 5 bar)}$

Temperature limits
- special steel, Material No. 1.4571 up to 500 °C
- special steel, Material No. 1.4571 up to 180 °C (coated)
- special steel, Material No. 1.4762 up to 600 °C
- silicon carbide up to 1,300 °C, max. length 1,000 mm

Flow rate
Max. 300 l/h

Pressure drop
approx. 10 hPa (mbar) at flow rate of 30 ... 90 l/h

Mounting
G 3/4 external thread DIN ISO 228/1

Mounting angle
any; 8° to 90° downwards from the horizontal is recommended

Figure 1.17  Continued.
Use

- low gas temperature
- high moisture content in gas and
- corrosive components in the process gas

Typical places of use are:
- sampling points in wet desulphurisation plants (crude gas, clean gas, part-cleaned clean gas)
- waste incineration plants
- auxiliary boilers and stack emission measurements

Process gas sampling conditions

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
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</thead>
<tbody>
<tr>
<td>Wattage (W)</td>
<td>400</td>
<td>600</td>
<td>800</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

Probes tube heater

Heat output
- nominal length 1,000 mm: 2 x 200 W
- nominal length 1,500 mm: 2 x 300 W
- nominal length 2,000 mm: 2 x 400 W

Nominal voltage
230 V / 115 Hz

Control
- control temperature max. 200 °C

Temperature sensor
Pt 100

Continuous operation
- at 200 °C flue gas temperature 450 °C

Figure 1.17 Continued.
Use
For sampling hot cement flue gas with high dust content for CO, CO₂, NO, SO analysis in “dry” cement production (e.g. recuperator furnaces, furnaces with grate coolers); at rotary kiln inlet and/or after precalcination.

Process gas sampling conditions
Pressure
\[ p_{\text{abs}} = \text{max. } 200 \text{ kPa (2 bar)} \]
Temperature depending on fitted length \( L_1 \)
- max. \( 1,200 \, ^\circ \text{C} \) for \( L_1 \geq 3,500 \text{ mm} \)
- max. \( 1,300 \, ^\circ \text{C} \) for \( L_1 = 3,000 \text{ mm} \)
- max. \( 1,350 \, ^\circ \text{C} \) for \( L_1 = 2,500 \text{ mm} \)
- max. \( 1,400 \, ^\circ \text{C} \) for \( L_1 = 2,000 \text{ mm} \)
- max. \( 1,450 \, ^\circ \text{C} \) for \( L_1 = 1,500 \text{ mm} \)
Flow rate
max. \( 250 \text{ l/h} \)
Dust content
max. \( 2,000 \, \text{g/m}^3 \) (in conjunction with FE2 filter unit)
Dead time (\( T_d \)) for \( L_1 = 3,500 \text{ mm} \)
- approx. 40 s at 60 l/h, approx. 9 s at 250 l/h
90% time (\( T_{90} \)) for \( L_1 = 3,500 \text{ mm} \)
- approx. 82 s at 60 l/h, approx. 17 s at 250 l/h
Pressure drop
approx. 10 hPa (mbar)

Materials of the gas-carrying parts
Sampling tube: special steel, Material No. 1.4541

Mounting
A flanged probe connector (internal diameter 200 mm) should be installed by the customer. The mounting flange is essential for installing the probe tube.

Cooling water supply
Drinking water quality
- with approx. 30 % anti-freeze if required
Outlet temperature
- min. \( 50 \, ^\circ \text{C} \) (or > dewpoint of the cement flue gas),
- max. \( 85 \, ^\circ \text{C} \)
Pressure: \( p_{\text{abs}} = \text{max. } 400 \text{ kPa (4 bar)} \)
Quantity circulated
approx. \( 3 \text{ m}^3/\text{h} \) (closed system)

Figure 1.17  Continued.
**Figure 1.19** Special case T-flange sample valve for inline liquid sampler. Reprinted, with permission, from Sampling Systems, a Division of PMMI Inc.
Figure 1.20 Inline liquid sampler. Reprinted, with permission, from Sampling Systems, a Division of PMMI Inc.
Figure 1.21  Fixed volume liquid sampler (operating sequence). Reprinted, with permission, from Sampling Systems, a Division of PMMI Inc.
Figure 1.22  Fixed volume liquid sampler (protection box door is closed). Reprinted, with permission, from Sampling Systems, a Division of PMMI Inc.
Figure 1.23  Fixed volume liquid sampler (protection box door is open). Reprinted, with permission, from Sampling Systems, a Division of PMMI Inc.
Figure 1.24 pH probe mounted into CPVC process pipe threaded tee. Reprinted, with permission, courtesy of Sensorex Corp.

Figure 1.25 pH electrode for process pipe probe mount. Reprinted, with permission, courtesy of Sensorex Corp.
In-line pH and ORP electrodes, flow cells, fittings and cables

Parts covered by this specification sheet include: S660CD, S660CD-ORP, S661CD, S661CD-ORP, S662CD, 970167, 970168

CPVC pH AND ORP ELECTRODES FOR IN-LINE INSTALLATION

CUT AWAY DRAWING OF S660CD/ORP IN 3/4" TEE

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<tr>
<th>TEE</th>
<th>3/4&quot;</th>
<th>1&quot;</th>
<th>2&quot;</th>
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<tbody>
<tr>
<td>A</td>
<td>5.17&quot;</td>
<td>6.50&quot;</td>
<td>7.90&quot;</td>
</tr>
<tr>
<td>B</td>
<td>2.75&quot;</td>
<td>3.45&quot;</td>
<td>4.65&quot;</td>
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<tr>
<td>C</td>
<td>2.05&quot;</td>
<td>2.60&quot;</td>
<td>3.73&quot;</td>
</tr>
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</table>

note: mount tee at least 10 deg above horizontal

Figure 1.26 pH probe mount dimensions. Reprinted, with permission, courtesy of Sensorex Corp.
Figure 1.27 pH insertion/removal probe assembly. Reprinted, with permission, courtesy of Sensorex Corp.

Figure 1.28 pH insertion/removal probe detailed diagram. Reprinted, with permission, courtesy of Sensorex Corp.
Insertion/wet-tap pH and ORP electrodes, assemblies and cables (cont)

Parts covered by this specification sheet include: S675, S676, S677, S675TC, S676TC, S677TC, S655CD, S655CD-ORP, S655KD, S655KD-ORP, 970213, 970214, 970291

CPVC and KYNAR ELECTRODES

CPVC and KYNAR CABLES WITH CONDUIT CONNECTION (NO ATC)

CPVC and KYNAR CABLES EXPOSED CABLE CONNECTION (NO ATC)

Figure 1.29 pH insertion/removal probe dimensions. Reprinted, with permission, courtesy of Sensorex Corp.
Figure 1.30  pH electrodes showing different insertion lengths for insertion/removal probe. Reprinted, with permission, courtesy of Sensorex Corp.
1. GENERAL INFORMATION

FPC is a general purpose floating piston cylinder and was originally designed for crude oil sampling to comply with the new ASTM standard for vapor pressure of crude oil (VPCRx). Incorporated PVDF valves avoid all extensions from the cylinder and a mechanical stirrer serves for uniform samples.

If the FPC is used with MINIVAP VPS and/or MINIVAP VPSH, please pay attention to the maximum pressure:

- MINIVAP VPS maximum pressure is 400 kPa (55 psi)
- MINIVAP VPSH maximum pressure is 1000 kPa (145 psi)

1.1 Main Features

- Integrated inlet and purge valve
- Integrated valve for back pressure
- Quick connectors for inlet, purge and back pressure
- Manual shifting of the piston with the integrated stirrer
- Automatic back pressure at pressurized samples
- Manometer for sample pressure integrated in mixing handle
- Easy to clean
- Integrated rupture disk
- Lightweight and compact

1.2 Technical Data

<table>
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<th>Feature</th>
<th>Value</th>
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<tr>
<td>Maximum working pressure</td>
<td>7000 kPa (1000 psi)</td>
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<tr>
<td>Sample volume</td>
<td>250 mL</td>
</tr>
<tr>
<td>Connector for sample and back pressure</td>
<td>Swagelok Series QM</td>
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<tr>
<td>Material of piston and cylinder</td>
<td>stainless steel</td>
</tr>
<tr>
<td>Material of valves</td>
<td>stainless steel and PVDF</td>
</tr>
<tr>
<td>Material of O-rings</td>
<td>Viton (Kalrez on request)</td>
</tr>
<tr>
<td>Physical dimensions:</td>
<td>D x L = 48 x 415 mm</td>
</tr>
<tr>
<td></td>
<td>D x L = 1.9’’ x 16.3’’</td>
</tr>
<tr>
<td>Weight</td>
<td>approx. 2.5 kg (5.5 pounds)</td>
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</table>

Figure 1.31a Grabner Instruments' floating-piston-cylinder sampler, used for taking and preserving the sample integrity of pressurized liquid samples containing dissolved gases. Reprinted, with permission, from Petrolab Company.
2.2 MINIVAP FPC-250 Cross Section

1. Piston with O-ring and free volume in the back. The small O-ring is for better gliding only.
2. Stirrer plate
3. Cylinder tube
4, 5. Inlet head with inlet and purging valve
6. Inlet and purging quick connector
7. Protection plate and seal for quick connector
8. Stirrer rod with 1 mm bore
9. Back pressure head with back pressure valve
10. Manometer for sample pressure
11. Handle for manual stirrer

Figure 1.31b Grabner Instruments’ floating-piston-cylinder sampler, cutaway view. Reprinted, with permission, from Petrolab Company.

Figure 1.32 Analect CHEMEYE is essentially an FTIR analyzer close-coupled to a light-guide-type sampling probe. A powerful analyzer system in a very compact package. Reprinted, with permission, from Orbital Sciences Corporation—Applied Instrument Technologies.
Universal Analyzers Inc. offers a Steam Heated Filter that conforms to NEC Hazardous Location Class I, Division 1, Groups A, B, C & D. Ceramic, Stainless Steel and Borosilicate Glass filter elements are available in 0.1 to 10 Micron ratings. A Flood type Calibration Port is included. Blowback, with a 1 SCF Air Accumulator, is offered as an option with air or electrical valve actuation. The 270S Probe is available in a Weather-tight Nema 4X Enclosure for Outside Stack Locations.

Figure 1.33 Steam-heated gas sample filter with flood-type universal calibration and blowback with accumulator. Meets Class I groups A,B,C,D Division 1 electrical hazard rating. Reprinted, with permission, from Universal Analyzers Inc.
APPLICATION NOTE 1.1 Process Analysis without Sample Conditioning. Reprinted, with permission, from Axiom Analytical Incorporated.

PROCESS ANALYSIS WITHOUT SAMPLE CONDITIONING

W. M. Doyle, Axiom Analytical Inc.

Over the past several years there has been a steadily increasing application of process analysis directly in line. This has been particularly evident in the field of molecular spectroscopy, where a number of developments have contributed to the increased practicality of in-line analysis. These include the advent of smaller and more robust instruments, the development of powerful chemometric software techniques, the availability of fiber-optic signal transmission, and the development of extremely robust probes and other sample interfacing equipment. Despite its vigorous growth, process spectroscopy has received little publicity other than a few talks given at highly specialized conferences. This is largely due to the fact that many of the applications are shrouded in industrial secrecy.

In its purest form, in-line (or in-situ) molecular analysis involves the use of an optical immersion probe inserted into a continuous process line, a batch reaction vessel, or a recirculating loop on a reaction vessel. However, some processes are compatible with the use of a flow cell or a cross-line transmission sampling system in place of an immersion probe. This is the case if the process already involves small-diameter flow lines or if a sample can be diverted to a side stream without changing its physical or chemical properties and without requiring sampling conditioning other than temperature control.

Three different forms of molecular spectroscopy are currently in use for liquid process analysis; mid-infrared, near-infrared, and Raman spectroscopy. Theoretically, mid-infrared would appear to be the most attractive of the three since each band of a mid-IR “fingerprint” spectrum corresponds to a specific molecular vibration (1). As a result changes in molecular structure can often be tracked by simply monitoring the strength of a single band corresponding to a particular functional group (2). However, despite this attractive feature, the growth of mid-IR process analysis has been hampered by three factors: the extreme strengths of most mid-IR absorption bands, the sensitivity of mid-IR optical materials to chemical attack, and the lack of practical fiber-optic systems for use in the mid-IR. Although mid-IR has been used continuously on-line since the 1970s, its use has been largely restricted to a very small number of large chemical companies with the sufficient in-house expertise to deal with its specialized requirements. The recent advent of probes which use diamond as an ATR element offers the potential of more widespread use of process mid-IR, especially for short runs of complex high-value products (3, 4).

Near-infrared spectroscopy has some distinct instrumental advantages over mid-IR due to its much weaker absorption bands and the availability of both practical fiber-optics for signal transmission and robust optical materials such as sapphire and fused silica for use in transmission probes and flow cells (5). However, spectral interpretation is much more difficult in the near-IR due to the fact that the useable absorptions are generally restricted to overtones and combination tones involving CH vibrations. Within the past few years, modern “chemometrics” has come to the rescue, providing a variety of mathematical tools for performing process calibrations even in the presence of highly complex dependencies (6). These calibrations do tend to be quite time consuming, requiring large data sets covering all possible process conditions. As a result near-IR analysis is most generally used for products such as polymers and other commodity chemicals that are produced in sufficiently long production runs to justify the cost of calibration.

The processes that are the most attractive candidates for near-IR analysis often involve extreme conditions such as high pressures and temperatures, rapid temperature changes, aggressive chemistries, and adverse ambient environmental conditions. This, combined with the high level of reliability demanded by continuous in-line use has placed great demands on the reliability and performance of in-situ probes and other sample interfacing devices. Until the last year or so, in fact, limited probe reliability was a major obstacle to the widespread implementation of near-IR process analysis. The major weak point was the need for a highly reliable means for sealing between sapphire windows and the corrosive resistant materials used for the probe bodies. The two approaches most often used in the past have been elastomeric seals (O-rings and spring energized C-rings) and brazing. Both of these have proved to be problematical under harsh process conditions. Elastomeric seals tend to flow and take a set at high temperatures and to fail on temperature cycling. Brazes, on the other hand, fall into two categories: those that achieve good mechanical integrity by employing low expansion metals between the braze and the probe body and those that achieve good chemical resistance by eliminating
the low expansion metal. Unfortunately, this approach leads to extreme stress within the braze and, hence, eventual failure.

The problem of probe window attachment appears to have been solved within the past year and a half by the development of a technique involving the use of metal C-ring seals (generally gold-coated Hastelloy) captured within an electron beam welded structure (7). This development has already resulted in some highly successful installations which, in turn, have led to the development of plans for more widespread implementation.

Raman spectroscopy has only recently started coming into its own. Although it does have some practical hardware limitations, it also has some very attractive characteristics. In particular, the Raman spectrum features similar fingerprint region detail and functional group specificity as mid-infrared but without the limitations of mid-IR optical materials. This is due to the fact that a Raman spectrum is shifted to higher frequencies (in either the visible or the near-IR region) where common optical glasses and fused silica fiber-optics can be employed (8).

The requirements on Raman sample interfacing devices are similar to those encountered with near-IR probes. As a result the metal sealing technique developed for near-IR probes is now being applied to Raman probes, as well. This is one of several hardware advances required to turn Raman spectroscopy into a routine tool for process analysis.

In summary, three different forms of molecular spectroscopy are currently being used for the in situ analysis of a variety of chemical processes. Of these, near-infrared spectroscopy is by far the most advanced with numerous successful installations around the world. Recent advances in robust sample interfacing promise to aid in the expansion of near-IR applications to cover an even greater range of processes. In situ mid-IR has a long history but has been restricted to a fairly narrow range of applications, largely due to the limitations of mid-IR optical materials. However, recent probe developments combined with mid-IR’s ease of calibration promise to expand the use of in situ mid-IR, especially for expensive products involving short run batch processes. The use of Raman spectroscopy for industrial process analysis is still quite new. However, given continuing hardware improvements and instrument cost reduction, this branch of molecular spectroscopy is also likely to find widespread application.

---

**APPLICATION NOTE 1.2  Process Analysis without Sample Conditioning** (Reference Articles). Reprinted, with permission, from Axiom Analytical Incorporated.

**References**


