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NeSSI™ (New Sampling/Sensor Initiative)
Generation II Specification

A Conceptual and Functional Specification Describing the Use of Miniature, Modular Electrical Components for adaptation to the ANSI/ISA SP76 Substrate in Electrically Hazardous Environments

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△ **1.0 INTRODUCTION**

This functional and conceptual specification is based on the use of the miniaturized, modular analytical systems designed to the ANSI/ISA SP76.00.02-2002 standard substrate. This 2nd generation specification deals chiefly with integrating electrical components such as sensors and actuators (collectively referred to as transducers) onto the substrate in a manner suitable for use in electrically hazardous areas commonly found in petrochemical, refining and chemical facilities. The specification outlines a recommended environmental packaging guideline, which if practiced allows for application across many common industrial settings. This specification contains many ideas and recommendations originating from various End User, manufacturer and NeSSI™ *ad hoc* user group meetings and communications, and it shall be referred to as the "NeSSI design". NeSSI is an industry wide open initiative sponsored by the Center for Process Analytical Chemistry (CPAC) at the University of Washington, Seattle, Washington, USA. It is conceptual in that certain practices and methods are mentioned but are not yet commercially available on the market. This specification is intended as a vehicle for alerting the marketplace to the need for these types of products.

Replacing big with small will not bring fundamental change in the way we design, install and build process analytical systems. To take full advantage of the functional capabilities offered by the new NeSSI design, it must be "smart" in addition to providing a different (but standard) way of transferring signals and power onto and off of the sample system and sensor substrate. In order to make analyzer systems “smart”, low cost transducers must be built into the system and some degree of decentralized intelligence, including control, must be incorporated into the overall design. This specification is a 2nd generation “electrified” design for NeSSI. (See Figure 1) Table 1 provides a comparison of Generation I versus a Generation II “electrified” system as well as future (and out of scope for this specification) Generation III systems. To date, limited examples of the 1st generation systems have been successfully deployed as an integral component of sampling systems for gas chromatographs and other non-gas chromatographic analytical techniques. However, the current design does not lend itself to the "plug and play" functionality for the sensors, which are envisioned as an integral part of the NeSSI design. The substrate-mounted system brought about a freedom to design and place mechanical and mostly passive components for the appropriate task at hand. A similar method is needed to optimize the configuration and connectivity efficiency for the active, electrical and optical components. "Plug-and-play" capability will drive standardization in the industry, increase system reliability, contribute to providing safer systems and ultimately simplify and streamline process analytical sampling system design and engineering. The bottom-line benefits will be lower cost-to-build and cost-of-ownership which are the real economic drivers for the NeSSI effort.

Figure 1. NeSSI Generation Segmentation

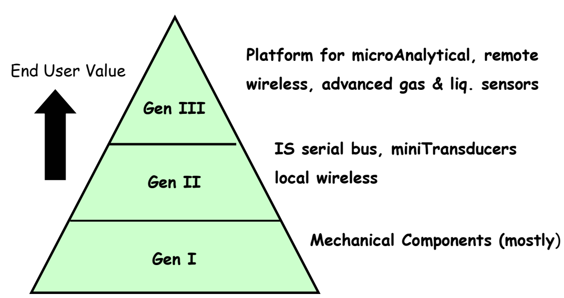

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Table 1. Comparison of NeSSI Generation Designs

Feature	Generation I	Generation II	Generation III
Transducer Communication	Analogue & Digital	Serial, multi-drop	Serial, multi-drop
Transducer Classification	Purging (Ex p), Flame Proof (Ex d) [typ.]	Low Power IS (Ex ib) Optional Ex ia; Encapsulation (Ex m)	Low Power IS (Ex ib), Optional Ex ib; Encapsulation (Ex m)
MicroClimate Enclosure Classification (Substrate)	Typically Div 1or 2	Div 1/Zone 1 (Optional Zone 0)	Div 1/Zone 1 (Optional Zone 0)
Enclosure Classification (SAM)	N/A	Typ. Div 2/Zone 2 (Optional Div/Zone 1)	Typ. Div 2/Zone 2 (Optional Div/Zone 1)
Transducer Location	Typ. off substrate	Typ. substrate mounted	Substrate mounted
Enclosure Heating (Substrate)	Add-on (Ex d)	Integrated (Ex d power); IS temperature measure & control	Integrated (Ex d power); IS temperature measure & control
Sensor I/O Signals	Hard-wired; typ. 4-20 mA; discrete I/O	Multi-drop serial bus (Intrinsically Safe)	Multi-drop serial bus (IS); some fiber optic
Signal Power	2-wire or 4-wire analog	Bus powered with signal	Mini-Power bus; IS bus
Intelligence	Limited	Smart	Smart
Control Philosophy	Centralized	Distributed (SAM)[1]	Distributed (SAM)
Regulating Components	Typ. self-contained spring & diaphragm; off substrate	Small components; control loops; on substrate	Small-components; control loops; on substrate
Sensor Transducers	Limited usage; expensive and large	P, T, F on substrate; low power mini design	microAnalytical sensors; fiber optic sensors; advanced sensors
Passive Components	Pure mechanical; both on and off substrate	Integrated mechanical and electrical; on substrate	Integrated mechanical and electrical; on substrate
Actuator Transducers	Pneumatic; off-substrate solenoid	Vo, Vm "combi": (pneumatic & electrical combined)	Vo, Vm, "combi" (pneumatic & electrical combined)
Substrate Heating	Add-on (Ex d power and control)	Integrated (Ex d power); IS control	Integrated (Ex d power); IS control
Power/Signal Wiring Methods	X-proof conduit/cable	Intrinsic Safe for transducers; Ex d for high power	Intrinsic Safe for transducers; Ex d for high power
Cost	High	High to begin….moderate	Moderate to low.
Analysis Style	Off-substrate	On and Off Substrate	On substrate preferred using MicroAnalytical
Communication to DCS & Off-substrate Analyzers	4-20 mA; discrete	4-20 mA; discrete; Wired Ethernet	Wireless and Wired Ethernet
Diagnostic Tool	n/a	Local Wireless PDA/PC Hand-held Device	Local Wireless PDA/PC Hand-held Device

[1] SAM = Sensor Actuator Manager

2.0 BACKGROUND

Process analytical instrumentation is big business - worldwide, it is almost a $5 Billion enterprise. Approximately $2.5 Billion a year is spent on care and maintenance of an installed base valued at $20 billion to $25 billion [2]. Significant rewards exist for those willing to innovate and take process analytics to the next level of efficient designs based on state-of-the-art (and emerging) technologies.

Although process analyzers have benefited from the incorporation of microprocessor technologies, extractive sample system design on the other hand, other than a few exceptions, has remained remarkably static since the advent of the first process analyzers in the late 1930's. There have been many reasons for this including the need to handle flammable mixtures with caution - and consequently a highly conservative attitude has become the norm throughout the industry. Indeed the original sample system designed by IG Farbenindustrie in Ludwigshafen, Germany for their oxygen and Luft infra red analyzers would not be considerably out of place today! However, significant advances and improvements have occurred in microprocessor, micro-machined fabrication and telecommunications (e.g. wireless, lasers) technologies just over the last few years. (Consider a modern car or house – there are dozens of inexpensive microprocessors silently at work). Leveraging these in conjunction with a better understanding of materials and explosion-proof techniques make process analytical sampling systems a prime target for R & R, "Review and Rejuvenation". Furthermore, a significant effort in MEMS based technologies has already resulted in "lab-on-a-chip" designs and micro-analyzers such as mass and infrared spectrometers. These micro-analytical devices are especially suited for incorporation onto a miniature, modular substrate and manifold. Longer term, NeSSI is well positioned as the enabling platform for the next generation micro-analytical sensors and analyzers. NeSSI therefore provides a mechanism to bridge the macro world of process sampling to the micro world of micro-analytics.

An issue with today's sampling system technology is the lack of standardization throughout the industry. In fact, the use of discrete and non-standardized designs has resulted in a "custom" design approach and a systems integration industry to specifically support custom sampling system designs. Although this can be argued, the majority of application specific sample system functions could be standardized across industry. The End User community by and large has not taken the appropriate steps to collectively combine their best practices. It is the contention of the NeSSI effort that a miniature, modular and smart system can help standardize 80% or so of the "common" design. The remaining customization can be readily accomplished by the "plug and play" capabilities of miniature, modular components.

3.0 INTENT OF THE SPECIFICATION

△ The intent of the specification is to outline the NeSSI functional and conceptual design parameters and techniques to make the sample system "smart", self-contained and "electrified" to meet the hazardous area requirements. By writing this specification, interested parties such as system integrators, analytical device manufacturers and vendors, and sensor producers/developers are invited to build components, sensors and devices suitable for the "next generation" sample and analytical system. The NeSSI Gen II specification will be the basis to build prototype designs. These designs will be alpha tested at the primary/lead manufacturer's facility. The beta prototypes will be tested in the End User facilities. The aggregate results will be reported back to the Beta testers, as well as CPAC and any funding agencies involved with these projects. The desired outcome is to commercialize Generation II products and serve as an enabler for microAnalytical (Gen III) products. Concurrent with this activity CPAC plans to promote the miniaturization of analytical devices (sensors and complete micro-analyzers) for mounting on the substrate and testing in their facilities.

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[2] Analytical Instrument Industry Report Volume 17, Issue 1, Page 4; 26th April 2000. From PAI/2000 - *The Worldwide Process Analyzer Market*. PAI Partners (Leonia, NJ) and Walton Associates (Menlo Park, CA)

The specification will introduce the "rail" concept using industry standard rails (mechanical and electrical) as an enabler and platform for both Generation II transducers as well as for Generation III microAnalytical devices. (See Figure 2) The specification will also be used to introduce serial communication as well as safe, robust low-power intrinsically safe electrical devices for use with process analytical sampling systems.

The specification shall be kept "evergreen" in order to serve as a vehicle to periodically communicate recommendations and improvements derived from Generation II prototype fabrication and commercialization. This document shall also serve as the basis for Generation III designs.

Figure 2. NeSSI "Rail" Concept

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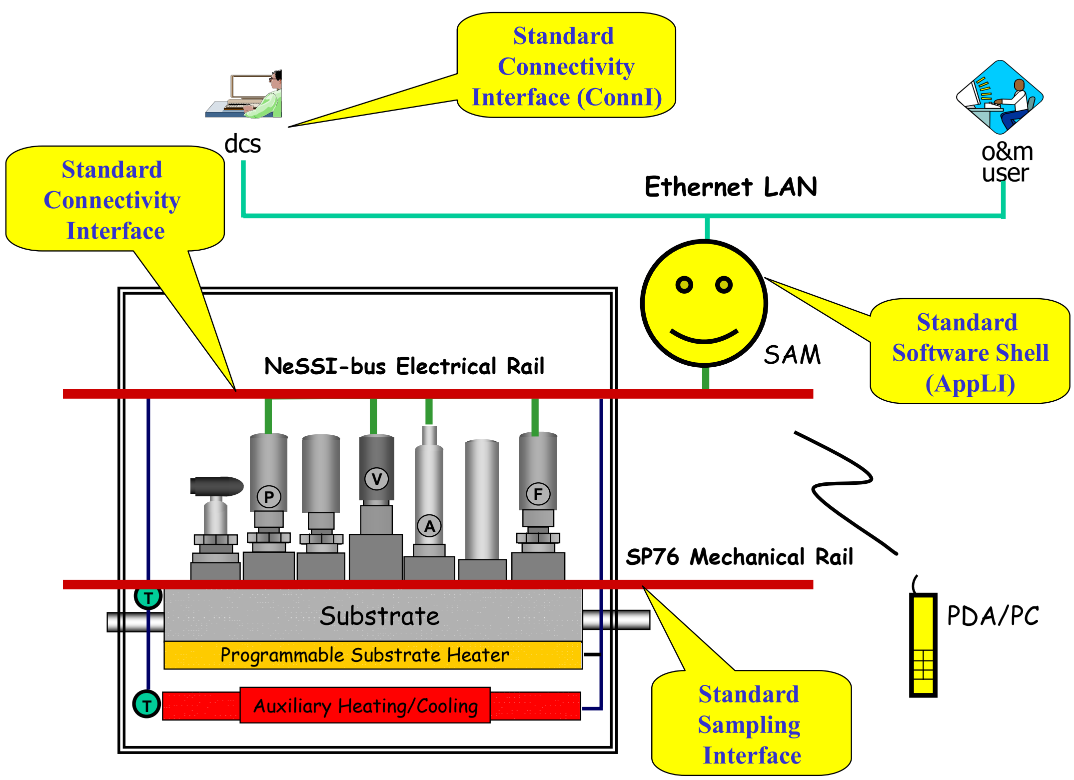

4.0 HAZARDOUS AREA STANDARDS AND CERTIFICATIONS FOR NESSI

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4.1 Global Hazardous Certification

The majority of analytical systems required for the petrochemical and refining industries are located in Hazardous Electrical Locations [3]. Consequently all NeSSI components – including transducers, wiring systems, optical systems, enclosures – must be designed to meet the various global Hazardous Location standards. In order to have broad appeal, NeSSI components must be designed to NEC (US); CEC (Canada); CENELEC/ATEX (Europe); GOST (Russia) and IEC (International Electrotechnical Commission) standards. Additionally all components should be certified or capable of being certified by the various international Certification Agencies including UL, FM, CSA as well as the various European and Asian certification organizations.[4].

△

4.2 A Preferred Hazardous Area Classification for NeSSI

The NeSSI specification favors the use of Division 1 (Zone 1) rated equipment inside equipment enclosures which handle hazardous (flammable) fluids. Designing to this capability, although more stringent than Division 2/Zone 2, will provide increased design flexibility, lower cost to build, simpler maintenance, optimum safety and suitability for the widest range of applications and requirements. Division 1 (Zone 1) will allow the use of analyzer optical windows, as well as dynamic and static elastomer seals, without the need for additional electrical protection methods such as purging, continuous dilution or pressurization. Considering that Generation II is a "from scratch" design specification, the intent is to provide a flexible and high safety design environment; this will obviate the need for interpretation of requirements for each application. Although possibly more difficult to design, it is anticipated that in the long run this will be the most cost effective electrical classification method.

4.3 Some NeSSI Goals

The overall NeSSI goal is to reduce analytical capital costs (cost-to-build) as well as long-term costs of operation (cost-of-ownership) by minimizing utility and sample conditioning requirements.

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4.3.1 Minimize Costs Associated with Hazardous Protection

One option is to minimize the need for pressurization, purging and dilution techniques (collectively called Pressurization and designated by symbol Ex p by the IEC) for NeSSI components within enclosures. Although convenient, pressurization methods of protection are not only costly to purchase but are also expensive to operate requiring large flows of clean gas. In some cases, for example in the need for inert pressurization, additional oxygen depletion hazards are presented which must be accounted for. Pressurization methods of protection are also subject to numerous regulatory interpretations (i.e. international installation and method variations) which make many new installations unique, suitable for only a specific geographic area and subsequently more design intensive.

4.3.2 Reduce Component Utility Consumption

Smaller components and tighter packaging will tend to lower cost of ownership due to reduction in utility (power, instrument air, cylinder gas, etc.) requirements.

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[3] A hazardous area is designated as any location in which a combustible material is or may be present in the atmosphere in sufficient concentration to produce an ignitable mixture.

[4] Presently there is an effort to create an international certification system, under the umbrella of the IEC. A branch of the IEC, called the IECEE, has established a working group to address this matter. This would be highly useful for a global effort such as NeSSI.

△ 4.3.3 Sample Flow Reduction
Installing systems "By-Line" [5] will require less flow typically by one order of magnitude. Not only will this reduce the "conditioning load" requirement, but will reduce "wasted" product.

4.3.4 Reduce Maintenance
By automating process analytical systems maintenance can now be predictive rather than preventive in nature.

4.3.5 Reduce Fabrication Labor and Design Time
Standard mechanical and electrical connectivity platforms as well as "design configurator tools" will reduce labor and design time.

4.4 Recommended Methods of Protection for NeSSI™

△ For a listing of various Methods of Protection refer to Table 2. (Special techniques such as wireless and optical may also serve as "special methods" of meeting electrical requirements.) Figure 3 outlines the electrical classification of a Gen II NeSSI system.

4.4.1. Class (type of hazardous atmosphere)
4.4.1.1 All NeSSI components shall be designed for Class I - gas or vapour atmospheres

4.4.2 Groups (based on ignition properties)
4.4.2.1 In general, electrical components, within the NeSSI enclosure handling hazardous fluids, shall be designed for operation in IEC gas groups: IIC, IIB, IIA , I and North American gas groups: A, B, C, D. Components that do not meet these criteria may be acceptable in certain cases and may be treated as a special exception (e.g. Group A).

4.4.3 Temperature T-Rating [**6**]
4.4.3.1 Electrical components shall be designed to meet T4 (135°C) maximum operating (surface) temperature. As an option T3 (200°C) may be acceptable in certain cases (e.g. heaters) and may be treated as a special exception.

△ 4.4.4 Division and Zone [**7**] Methods of Protection
4.4.4.1 Substrate Components Inside Enclosure
NeSSI Enclosure (interior) mounted <u>substrate components</u> including transducers (sensors and actuators) and wiring systems shall be designed for Division 1 and Zone 1 operation when flammable gases and/or liquids are handled by the sampling components. [optional Zone 0] Intrinsic Safety (Ex ib) [Optional Ex ia] and Encapsulation (Ex m) are the preferred methods of protection. Note: Ex ib (single fault) may in some jurisdictions be less preferred since it does not universally cover Division 1 applications which by strict definition include both Zone 0 and Zone 1. Encapsulation (Ex m) is a recognized Zone 1 method for devices less than 100 cc in volume. The reliability and ruggedness of digital transducers lend themselves to miniaturization, which will be enhanced by the use of Encapsulation (Ex m) protection methods.

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[5] By-Line Analysis is defined as an extractive sampling method, which performs the analysis within close proximity to the pipe, stack or vessel.
[6] The temperature category defines the maximum surface temperature of the device. Ratings are given with reference to 40° C.
[7] IEC uses the Zone system. North America has used the Division system, however current and emerging North American regulations will now be built on the Zone system. (Canada accepts the Zone regulation for new installations.)

4.4.4.2 Non-Substrate Components Inside Enclosure

NeSSI Enclosure (interior) mounted auxiliary components (e.g. heaters), not mounted on the substrate or directly heating the substrate and unsuitable either due to power requirements or by availability shall be designed for Division 1 and Zone 1 operation. Explosion/flame proof (Ex d) is the preferred method of protection. Certain heating techniques may require integral over-temperature shut-off or redundant shutdown mechanisms to meet the T-Rating requirements.

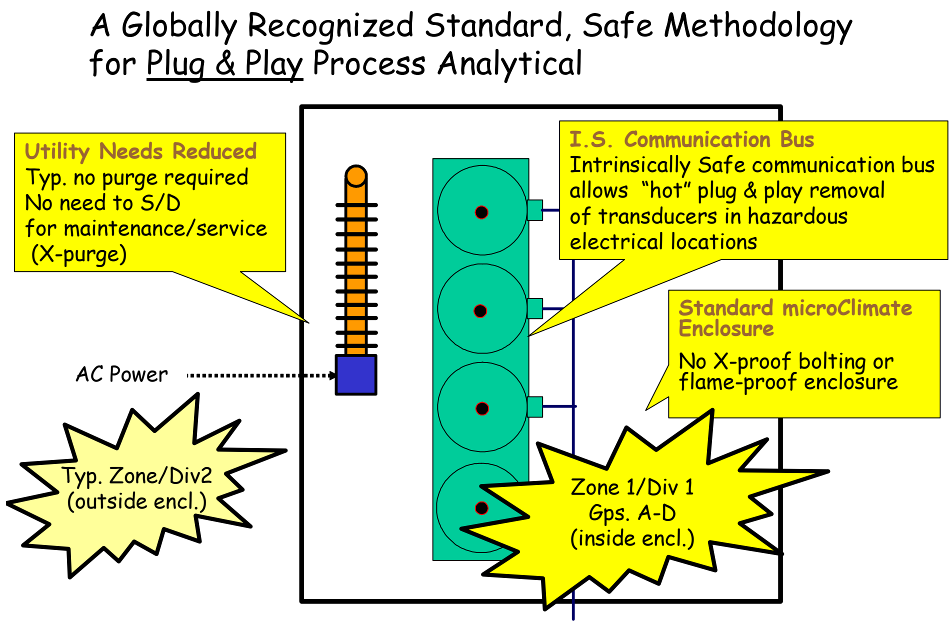
4.4.4.3 Exterior (outside) of the NeSSI Enclosure

The NeSSI (exterior) mounted components and wiring systems shall be designed for Division 1/Zone 1, Division/Zone 2, or general purpose as per the facility local area classification. A minimum of Div/Zone 2 certification is recommended for widest application. (Various protection methods include Ex d flameproof condulet.)

Table 2. IEC Recognized Methods of Protection (for reference)

Technique	IEC Symbol	Permitted Zone
Oil Immersion	Ex o	1 & 2
Pressurization	Ex p	1 & 2
Powder Filling	Ex q	1 & 2
Flameproofing (Explosion Proof)	Ex d	1 & 2
Increased Safety	Ex e	1 & 2
Intrinsic Safety (2 fault tolerant)	Ex ia	0, 1 & 2
Intrinsic Safety (1 fault tolerant)	Ex ib	1 & 2
Non-incendive	Ex n	2
Encapsulation	Ex m	1 & 2

Figure 3. Global Electrical Classification



4.5 RFI and EMI Rejection

NeSSI components must be immune from Radio Frequency Interference (RFI) and Electro Magnetic Interference (EMI). Consequently all electrical components for NeSSI™ shall bear the CE certification mark.

5.0 CORE ELEMENTS OF THE GENERATION II DESIGN

A Generation II NeSSI™ system will contain core elements as illustrated in Figure 4.

5.1 MiniSensor Transducers [8]

△ 5.1.1 IS-certified, Temperature (T), Pressure (P), Flow (F) miniSensor/Tranducers, with embedded signal conditioning and communications components (NeSSI-bus micro-controller, integral A/D and transceivers) suitable for operation on the intrinsically safe NeSSI-bus.

5.1.2 ANSI/ISA SP76 form factor

5.1.3 IS-certified Temperature (T) Sensor for monitoring the substrate base temperature.

5.1.4 IS-certified Temperature (T) Sensor for monitoring the microClimate Enclosure temperature.

5.2 Programmable Heated Substrate Base

5.2.1 Heater shall be integrated into the substrate base or a mounting plate assembly.

5.2.2 Substrate temperature and heating control shall be integrated into SAM and the NeSSI-bus.

5.2.3 Heater certified for Ex d.

△ *5.3 "Combi" Valve - Actuator Transducers*

5.3.1 Pneumatic/electrical hybrid combined valve assembly ("combi").

5.3.2 ANSI/ISA SP76 form factor.

5.3.3 Certified for low-power Intrinsically Safe (IS) operation - Ex ib minimum (optional Ex ia).

5.3.4 On/Off Valves (Vo).

5.3.5 Modulating Valves.(Vm)

5.3.6 Embedded NeSSI-bus communications with integral D/A and A/D conversion.

△ *5.4 Multi-drop, Serial Sensor/Actuator (Transducer) NeSSI-bus* [9]

5.4.1 IS-certified "the NeSSI-bus" - Ex ib minimum (optional Ex ia).

5.4.2 Multi-drop serial, low-cost communication.

5.4.3 Network controller in SAM.

5.4.4 A standard electrical mini-connector for all transducers.

5.5 Temperature Controlled microClimate Enclosure

5.5.1 Heated microClimate enclosure.

5.5.2 Enclosure temperature and heating control integrated into SAM and the NeSSI-bus.

5.5.3 Certified heater for Ex d.

5.6 Sensor Actuator Manager (SAM)

△ 5.6.1 The Sensor Actuator Manager shall be a low cost, robust, miniature (hockey-puck size) computing device packaged for hazardous area industrial applications. It is envisioned as the industrial equivalent to a workstation with open architecture furnished with an industry common operating system (Windows or Linux).

5.6.2 SAM is a sampling system controller AND a communications gateway/bridge to exchange measurement and configuration data between the NeSSI-bus sensors/actuators.

5.6.3 SAM provides a high level Ethernet connection typically to a remote analyzer or DCS. SAM may also be packaged as part of an analyzer/controller (embedded configuration).

5.6.4 SAM serves as a host for both local and remote wireless connectivity.

5.6.5 SAM may also be used as a microAnalytical device manager by using dedicated software space for developers.

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[8] The term transducers used in this specification includes both miniSensors and actuators.
[9] The term NeSSI-bus is used generically in this specification for an intrinsically safe commercially available bus.

5.6.6 Contains a software shell and platform for common typical sample system control and monitoring applications which are commercially available. (Appl-I)
5.6.7 Certified for Div/Zone 2 minimum. (optional Zone/Div 1)

5.7 Local Wireless Human Machine Interface (HMI)

△ 5.7.1 A Zone 2/Div 2 portable (preferably wearable) device (e.g PC or PDA) shall be capable of short-range wireless connection to the SAM. The full functionality of the SAM shall be accessed by this device/tool. (Note: A fixed, hard wired operator display terminal is not cost effective for each SAM).

5.8 Stretch Elements of a Generation II NeSSI Design

5.8.1 Simple Analyzers which can be mounted on the ANSI/ISA SP76 substrate which communicates by means of the Intrinsically Safe NeSSI-bus.
5.8.2 Advanced Appl-I "applet" programs.

Figure 4. Seven Elements of a Gen II Prototype

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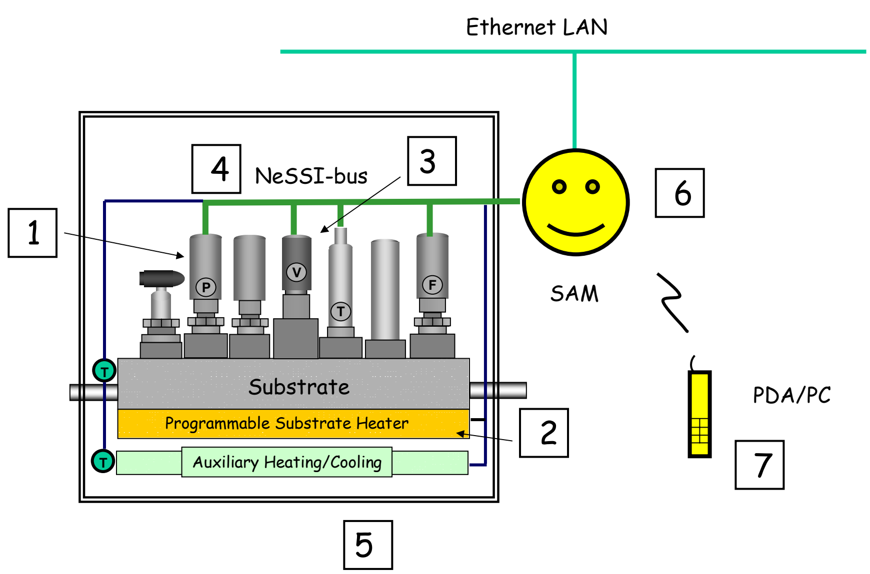

6.0 MINISENSOR TRANSDUCERS

6.1 Purpose

Performing an analytical measurement and validating the measurement does not mean that the results are correct. Especially for extractive sampling techniques, flow, pressure and temperature sensors, among others, are required to validate the goodness of the sample by determining whether the sample being measured is "fresh". Additionally flow, pressure and temperature are used to provide primary measurements to allow control of final elements such as valves and heaters. For example, sample systems can be kept above their dewpoint temperatures through temperature control and at a fixed pressure for optimum analysis. Miniature sensors (and actuators) allow replacement of much larger spring and diaphragm mechanical devices.

6.2 Physical Transducer (miniSensor) Types

6.2.1 Flow Transducers

△ A considerable opportunity exists for those who can provide a cost effective ANSI/ISA SP76 electronic flow sensor to the Process Analytical industry. All extractive, self-validated analytical systems need some means of measuring flow. Traditional, legacy sample designs have relied on glass rotameters and needle valve restrictor combinations. Glass designs, for safety reasons, have gradually evolved to more expensive metal rotameters with magnetic coupled indicators in many conventional as well as higher-pressure applications. Currently the thermal mass flow meter/controller fulfills the majority of the electronic flow sensing/control market needs. These are very common in the semiconductor industry. Issues with today's electronic mass flow meters (MFC's) and their associated variable solenoid flow valves and controllers include lack of Division/Zone 1 certification, high costs, no local indication, unwieldy multi-pin connector, high power consumption as well as a relatively large size. There is a need for inexpensive, low power, substrate mounted miniature flow measuring devices whose accuracy specifications are less rigorous.

A low cost mass and volumetric flow meter is meant to supplement or eliminate traditional components such as rotameters. Any MFC employed should be capable of having local flow indication (for local maintenance use) as well as remote connectivity. Although certain MFC's come equipped with an attached solenoid controller/valve to maintain the flow set point, an alternative is a substrate mounted "combi" actuator/valve that can be used for "close loop" control by means of the SAM. A simple flow device can also be used in conjunction with a manual ANSI/ISA SP-76 needle valve for less rigorous applications.

Applications for microSensors for flow include process sample and bypass flows as well as utility flows required for usage calculations. Having continuous, real time flow sensors in an analytical system is probably one of the most important diagnostic tools for an analytical system.

Certain applications (pilot plant) may require higher accuracy mass flow and density transducers.. Consideration should be given to the provision of modular microCoriolis devices which can be adapted for use on the NeSSI-bus.

6.2.2 Pressure Transducers

Pressure is typically measured using a pressure gauge (local indication) or by an off-substrate pressure transmitter. Pressure gauges add dead volume in a low-volume substrate system and should be avoided if possible. Small microSensor type devices are ideal for substrate mounting. Fiber optic pressure sensors may also be a viable alternative.

Pressure sensors can be used for…

- The process control variable for use in controlling pressure by means of a final control element such as a combi valve mounted on the sample system substrate.

- Measuring system upstream pressures either on the substrate or in some instances at the sample tap by means of a sensor mounted integral to a regulating device.
- Measuring downstream pressures by means of an absolute pressure sensor allow mathematical compensation for pressure sensitive analyses such as spectroscopy caused by fluctuating sample return pressures. Furthermore this pressure signal can be used to control the pressure by means of a modulating combi valve. (Vm)
- Measuring atmospheric pressures (absolute pressure sensor is ideal) for compensating for atmospheric pressure fluctuations for chromatography sample injection.
- Serving as differential pressure sensors which can be built across a filtration substrate module to give a predictive warning of filter pluggage. The need therefore exists for differential, gauge and absolute pressure microSensors.
- Serving as diagnostic sensors for utility fluids (e.g. gas cylinder pressures, instrument air pressure, etc.) needed to service the system.
- Serving as diagnostic tools for use with software routines that are run to validate leak integrity of a complete system or circuit. (e.g. checking condition of a multi-valve system on a periodic basis.)

△ 6.2.3 Temperature Transducers

Temperature in many systems is measured, in some cases, with bimetallic or filled temperature gauges or simple thermostats. Temperature sensors, due to their small size and cost, are ideal devices to adapt to the substrate or be incorporated into specific components (e.g. heater). RTD (resistance temperature detector) sensors, with their inherent linearity, wide range and small size are good choices for substrate mounting. (Other temperature measurement transducers such as thermocouples or thermistors may be acceptable.) There are several applications for temperature monitoring which may be required for NeSSI. These include:

- Monitoring and control of the substrate mounting block temperature provides optimum operating conditions for both sample conditioning and analysis. The temperature of the block serves as the process variable for control of the substrate heating system.
- Temperature monitoring (and control) of the microClimate enclosure shall allow precise control of the system environment to maintain heat under diverse climatic conditions. The temperature of the enclosure serves as the process variable for control of the microClimate enclosure.
- Process Temperature (Flowing Stream) monitoring ensures that the system dewpoint and bubble point temperatures can be easily achieved without designing custom solutions for each application.
- Monitoring the temperature of each transducer as a diagnostic to ensure each device is operational and being kept at its optimum temperature.

Figure 5 summarizes the design requirements of a substrate mounted miniSensor Transducer. Table 5 lists the physical transducers requirements.

Figure 5. miniSensor Transducer for Substrate Mounting

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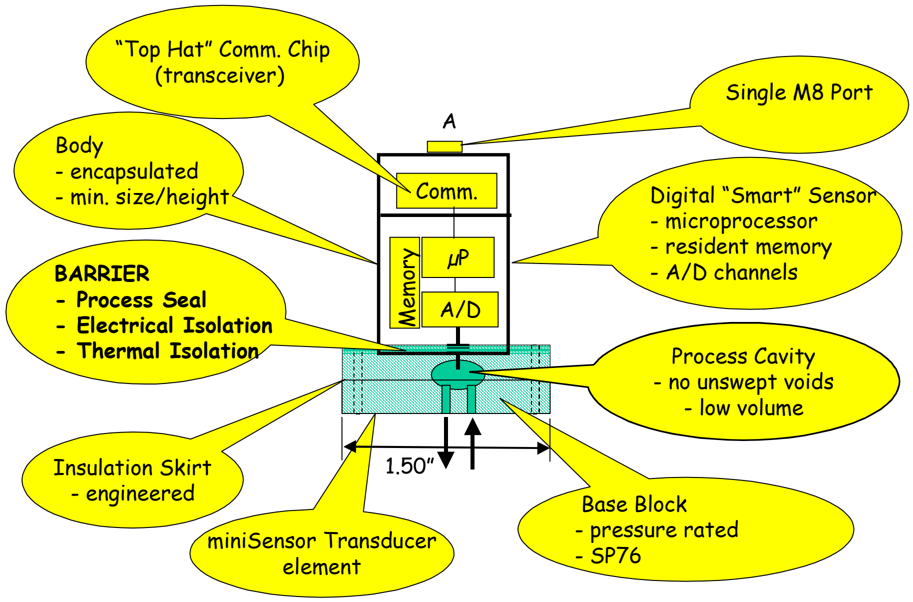

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Table 3. Physical Transducer (Sensor) Requirements

Flow Sensors	Range	Accuracy	Notes
Gas/Vapor			
Low Sample Flow	3-200 cc/min	±5% of span	Also configurable in SCFH.
Medium Sample Flow	3-2,000 cc/min	±5% of span	Also configurable in SCFH.
High Bypass Flow	10-5,000 cc/min	±5% of span	Also configurable in SCFH.
Liquids			
Low Sample Flow	1-300 cc/min	± 5% of span	Also configurable in GPH.
High Bypass flow	1-1,500 cc/min	± 5% of span	Also configurable in GPH.
Combination Gas and Liquid			
Low Sample Flow	3-200 cc/min gas or 0-300 cc/min liquid	± 5% of span	Configurable for liquid and/or gas (software selectable) Also configurable in SCFH/GPH
High Bypass Flow	10-5,000 cc/min gas or 3-1,500 cc/min liquid	± 5% of span	Configurable for liquid and/or gas (software selectable) Also configurable in SCFH/GPH
Temp. Sensors			
Wide Range	-50 to 200 °C	±0.2% of span	3-wire 100 Ω Pt RTD; DIN .385; software rangeable e.g. 0-50 C, 0-100 C, etc.
Pressure Sensors			
Low Range Gauge (common)	0-30 psig (0-2 bar)	±0.5% of span	Also configurable in kPa, bars
Mid Range Gauge (common)	0-150 psig (0-10 bar)	±0.5% of span	Also configurable in kPa, bars
Hi-Range Gauge	0-500 psig (0-34 bar)	±0.5% of span	Also configurable in kPa, bars
Hi-Hi Range Gauge (rare)	0-2000 psig (0-138 bar)	±0.5% of span	Also configurable in kPa, bars
Low-Low Range Absolute	1-15 psia (.07-1 bar)	±0.5% of span	Also configurable in kPa, bars
Low Range Absolute	1-30 psia (.07-2 bar)	±0.5% of span	Also configurable in inches water, mm water, inches Hg, inches Hg, atmospheres, kPa, bars
Medium Range Absolute	0-150 psia (0-10 bar)	±0.5% of span	Also configurable in inches water, mm water, inches Hg, inches Hg, atmospheres, kPa, bars
Low Range Differential	0-5 psid (0-.35 bar)	±0.5% of span	Also configurable in bars and kPa
High Range Differential	0-30 psid (0-2 bar)	±0.5% of span	Also configurable in bars and kPA

6.3 Physical miniSensor Transducer Hardware Specifications

△

6.3.1 General Requirements

6.3.1.1 The sensor shall be suitable for use with either liquids or gases or preferably both

6.3.1.2 The sensor shall be temperature compensated over the following ranges:

6.3.1.2.1 Preferred operating temperature range: - 40 to 120 C.

6.3.1.2.2 Less preferred but common temperature range: - 20 to 80 C.

6.3.1.2.3 Widest useful temperature range: -50 to 150 C.

6.3.1.3 Storage & Shipping Temperature: - 50 to 150 C.

6.3.1.4 Networkable (multi-drop and serial communication) with other “combi” actuator transducers via the NeSSI-bus.

6.3.1.5 The sensor shall be certified for Ex ib (intrinsic safe) operation.

6.3.1.6 The sensor shall come with on-board transducer, an A/D or D/A converter, a microprocessor, an EEPROM memory chip and a communication transceiver.

6.3.1.7 The sensor shall bear the CE mark.

6.3.1.8 Proof Pressure: The sensor shall withstand 1,500 psig as a minimum (otherwise 1.5 x maximum operating pressure) without rupturing.

6.3.1.9 Transducer shall be attitude and orientation independent.

6.3.1.10 A useful feature would be some type of low-power usage local indication (e.g. LED strip, digital display, etc.)

6.3.1.11 Transducers shall operate under vacuum.

6.3.2 Form Factor & Fabrication

6.3.2.1 The sensor shall meet the NeSSI ANSI/ISA SP-76 footprint requirements.[10] Refer to Figure 6.

6.3.2.2 Seals: elastomer O-rings on the base of sensor

6.3.2.3 Sensors to be thermally isolated internally (i.e. sensing element chamber should minimise heat losses i.e. conduction/radiation away from the process wetted parts or into the electronics)

6.3.2.4 The sensor shall be incapable of passing process fluids into the wiring connection system or electronic section under a fault condition (e.g. in case of rupture).

6.3.2.5 The sensor shall be encapsulated/potted and be hermetically sealed (non-user repairable).

6.3.2.6 The sensor should meet Ex m certification criteria.

6.3.3 Electrical Connectors

6.3.3.1 The transducer shall be provided with a standard single non-proprietary industrially rugged male connector. The miniature connectors shall be suitable for all physical variants of the selected communication protocol. A preferred connector is the M8.

6.3.3.2 The connector shall be located on the top of the transducer.

6.3.4 Process Wetted Parts

6.3.4.1 Standard process wetted metal parts shall be: 316L Stainless Steel, Optional: Monel® 400, Hastelloy® C-22 or C-276, Teflon® PFA, PVDF (Kynar®)

6.3.4.2 Standard process wetted elastomer seal materials of construction (elastomers) shall be: Viton® (FKM). Optional: Kalrez®, Teflon, EPM

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[10] ANSI/ISA-76.00.02-2002
Modular Component Interfaces for Surface-Mount Fluid Distribution Components-Part 1: Elastomeric Seals

6.3.5 Non-Process Wetted Parts Exposed to the Atmosphere

6.3.5.1 Shall be fabricated from either anodised aluminum, rugged plastic polymer, or stainless steel

6.3.6 Transducer (Sensor) Electrical Power

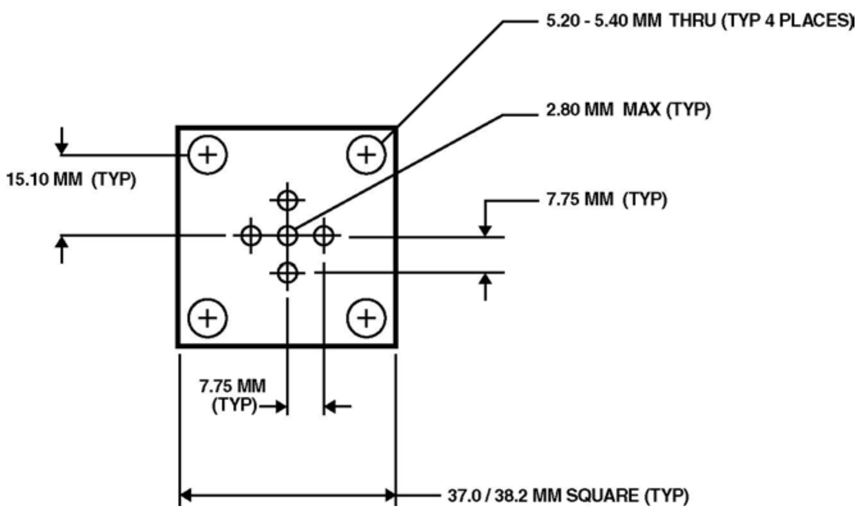
6.3.6.1 Both sensor communication power and sensor operating power shall be powered most preferentially from a galvanically isolated intrinsic safe power supply and less preferentially through a zener diode intrinsic safety barrier. [11]

6.3.6.2 Electrical power shall be +10 to +24 VDC for the sensor/transducers. NeSSI recommends a "standard" voltage such as +12 VDC for all transducer power.

6.3.6.3 NeSSI recommends a 'standard' minimum voltage for the communication transceiver, for example 3.3 Volts.

6.3.6.4 In order to cluster many sensors onto one network NeSSI recommends a power allocation of 20 to 60 mW/transducer typically with a current draw (at 12 VDC) preferably less than 2 mA and no greater than 5 mA.

Figure 6. ANSI/ISA SP76 "Footprint"



[Refer to ANSI/ISA 76.00.02-2002 for complete details]

6.4 P. T. F. MiniSensor Transducer Software Features

6.4.1 The transducer shall be capable of plug and play identification, (e.g. tag numbering, part number, etc.)

6.4.2 The transducer input or output signal shall be capable of being configured for various engineering units over various pressure, temperature and flow ranges.

6.4.3 The transducer shall have on-board diagnostics including– heartbeat, self-testing routines, etc.

[11] Galvanic Isolation barriers do not require a high integrity grounding system.

6.4.4 The transducer shall be capable of being software configured for: – liquid vs. gas selectable, engineering span rangeability, (e.g. ability to calibrate over a portion of a wider range), temperature compensation adjustments, specific gravity factor, etc.

7.0 "COMBI" VALVE TRANSDUCER ACTUATOR

7.1 Purpose

Actuators are needed for both on/off actuation as well as modulating (variable) control. Traditional actuation modes have either been manual or pneumatically operating. An automated, substrate mounted actuator will allow on-board control of parameters typically done with larger spring/diaphragm controlled regulators. Since conventional solenoid operating devices do not have the power to operate "intrinsically safe" NeSSI proposes the use of combined electro-pneumatic actuators packaged as a unit. (Refer to Figure 7a /b) This eliminates the tubing interconnections and specialized mounting requirements for standard solenoid to pneumatic valve actuator "trains".

Figure 7a. "Combi" Transducer On/Off (Vo)

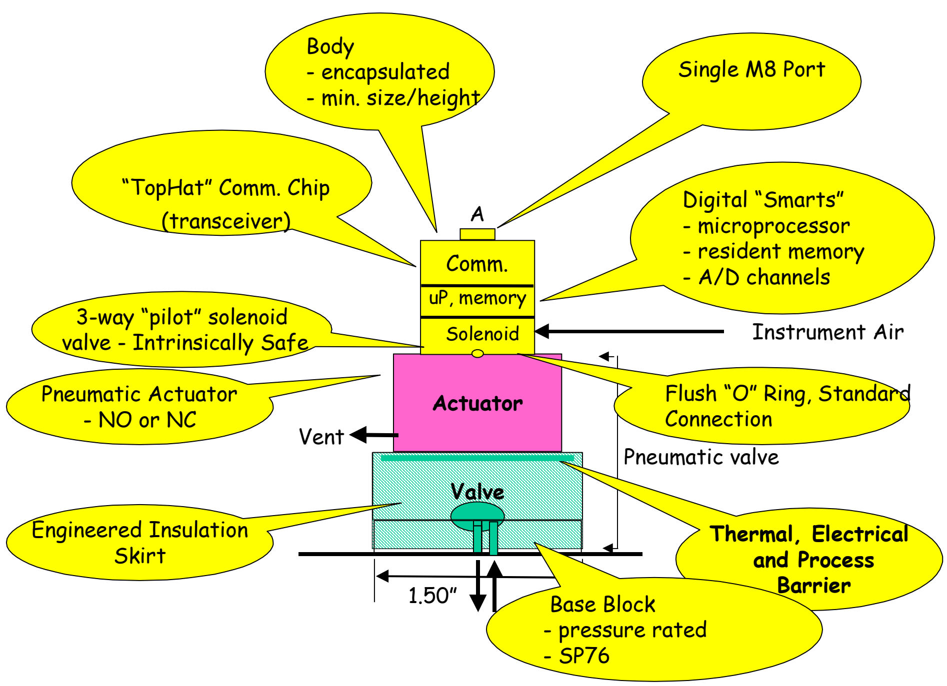
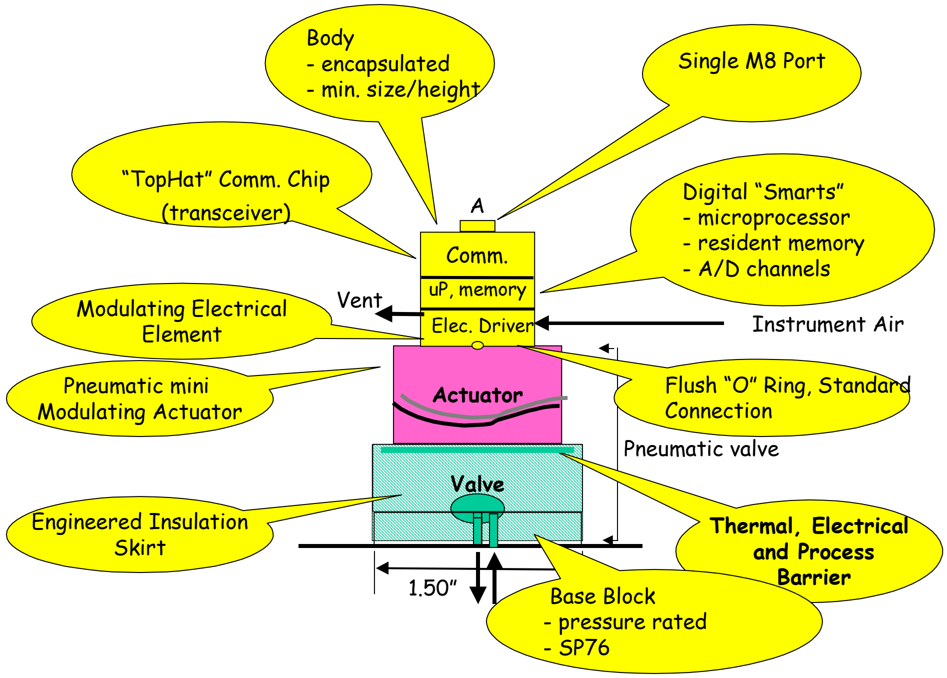


Figure 7b. "Combi" Valve Transducer Modulating (Vm)



7.2 "Combi" Valve Transducer (Actuator) Hardware Specs

△ 7.2.1 Application Parameters and General Specifications
- 7.2.1.1 Suitable for liquids and gases
- 7.2.1.2 The sensor shall be temperature compensated over the following ranges:
  - 7.2.1.2.1 Preferred operating temperature range: -40 to 120 C.
  - 7.2.1.2.2 Less Preferred but common operating temperature: -20 to 80 C.
  - 7.2.1.2.3 Widest Range of useful operating temperature: -50 to 150 C
- 7.2.1.3 Storage & Shipping Temperature: -50 to 150 C.
- 7.2.1.4 Networkable with mini transducer sensors via the NeSSI-bus.
- 7.2.1.5 Certified for Ex ib (intrinsic safe) operation. (optional Ex ia)
- 7.2.1.6 Proof Pressure: The combi valve shall withstand 1,500 psig as a minimum (otherwise 1.5 x maximum operating pressure) without rupturing.
- 7.2.1.7 The transducer (actuator) shall have the CE mark.
- 7.2.1.8 Actuator communication shall be multi-drop serial.
- 7.2.1.9 Transducer shall be attitude and orientation independent.
- 7.2.1.10 A visual position indicator shall be included (could be electronic indicator).

7.2.2 Form Factor & Fabrication
- 7.2.2.1 Shall meet NeSSI footprint requirements.
- 7.2.2.2 Seals: O-rings on base of actuator
- 7.2.2.3 Actuators shall be thermally isolated internally (i.e. sensing element chamber should minimise heat losses i.e. conduction/radiation away from the process wetted parts or into the electronics)

7.2.2.4 Shall be incapable of passing process fluids into the wiring connection system under a fault condition. (in case of rupture)
7.2.2.5 Shall be encapsulated/potted for hermetic sealing (non-user repairable). Recommend Ex m certification.

7.2.3 Electrical Connectors
7.2.3.1 Require a standard single non-proprietary industrially rugged water tight connector, miniature male connector. A M8 connector is recommended.
7.2.3.2 Connector shall be located on the top of the transducer.

7.2.4 Process Wetted Parts
7.2.4.1 Standard 316L stainless steel, Optional: Monel 400, Hastelloy C-22 or C-276, Teflon PFA, PVDF (Kynar)
7.2.4.2 Seals: Standard Viton (FKM) Optional: Kalrez, Teflon, EPM

7.2.5 Non-Process Wetted Parts Exposed to the Atmosphere
7.2.5.1 Anodized aluminum or rugged plastic, polymer or composite, stainless steel

7.2.6 Electrical Power
7.2.6.1+10 to +24 VDC, shall be used. NeSSI recommends standardizing on 12 VDC for the transducer power.
7.2.6.2 In order to cluster many sensors onto one network NeSSI recommends a power allocation of 20 to 60 mW/transducer typically with a current draw (at 12 VDC) preferably less than 2 mA and no greater than 5 mA.
7.2.6.3 Both sensor communication power and sensor operating power shall be powered most preferentially from a galvanically isolated intrinsic safe power supply and less preferentially through a zener diode intrinsic safety barrier.

7.2.7 Certification and Classification
7.2.7.1 As per hazardous criteria for NeSSI

△ 7.2.8 Pneumatics
7.2.8.1 Pneumatic actuators operate from min. 40 to max. 110 psig actuator supply pressure
7.2.8.2 10-32" straight (SAE) x 1/8" compression is the preferred pneumatic connection. (An SAE connector allows optimum connection flexibility for angle connectors.) Alternatively and less desirable is a 1/8" NPT x 1/8" compression pneumatic actuator connection.

△ 7.2.9 Valve Shut-off Seal
7.2.9.1 Typically Viton or Teflon "soft seal". Also Tefzel, polyimide, PCTFE, PEEK.

7.3.0 Electrical actuator to pneumatic valve attachment shall be flush mount and sealed by means of an O-ring seal. A (universal) standard flush interface connection design will be preferred. (NeSSI invites the submission of a design standard that accomplishes this.)

Table 4 lists the combi valve actuator requirements.

Table 4. "Combi" Valve Actuator Requirements

Actuator/Valve Types	Typical Operation Ranges	Configuration	Notes
On/Off Combi Valve (Vo)	Vacuum – 15 psig (Vacuum-1 bar) Vacuum - 50 psig (Vacuum to 3.4 bar) 0 -150 psig (0-10.3 bar) 0 - 500 psig (0-34.5 bar) 0 - 2000 psig (0-138 bar)	NO or NC 2-way and 3-way	Bubble Tight shut-off
Modulating Combi Valve (Vm)	Vacuum – 15 psig (Vacuum – 1 bar) Vacuum - 50 psig (Vacuum – 3.4 bar) 0 - 150 psig (0-10.3 bar) 0 - 500 psig (0-34.5 bar) 0 - 2000 psig (0-138 bar)	Fail Open and Fail Closed	At least 1% resolution over 0-100% stroke

△

7.3 Combi Valve Software Features

7.3.1 The transducer shall be capable of plug and play identification (e.g. tag number, part number, etc.).

7.3.2 The transducer input (% stroke) or output (% position) shall be capable of being configured for various stroke ranges (e.g. 0-100% stroke, 0-50% stroke, etc.).

7.3.3 The transducer shall be capable of providing diagnostics including – heartbeat, self-testing routines, monitor shut-off force, number of operations, etc.

7.3.4 Software shall be configurable for: liquid or gas operation, stroke, compensation modes, on/off or modulating mode, shut-off conditions, etc.

7.3.5 The combi-valve shall be capable of being manipulated by a PID algorithm located in the SAM.

8.0 MICROCLIMATE ENCLOSURE HEATING AND PACKAGING

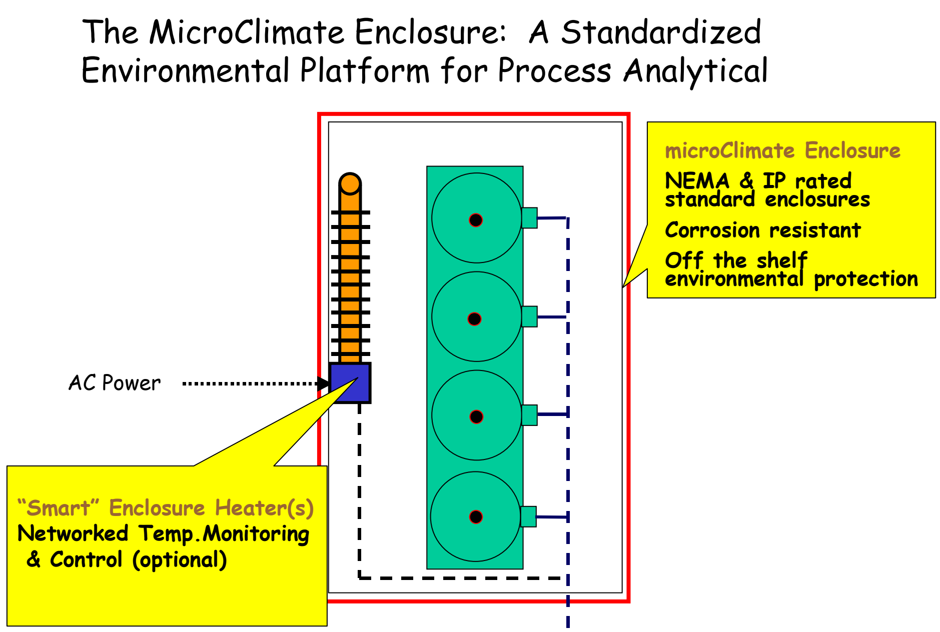
8.1 Purpose

The microClimate enclosure ratings provide appropriate protection for various outdoor installation climatic conditions including snow, precipitation, sunlight, "hosing down", ingress of dust, etc. Ambient temperature variations (outside of the enclosure) can range from -50 C in "arctic" areas to +50 C in tropical environments. Enclosures are also needed to protect against inadvertent contact and mechanical damage of electrical components by tools, fingers, etc. Additionally the enclosure serves as a temperature controlled environment to stabilize the ambient surroundings for NeSSI components. Refer to Figure 8 for an enclosure heating and packaging schematic.

8.2 Packaging

All apparatus contained within the enclosure will be assembled, tested for functionality and electrically approved as an entity.

Figure 8. MicroClimate Enclosure Package



△

8.3 MicroClimate Enclosure Requirements

8.3.1 Enclosure Protection - Outdoor Type

8.3.1.1 Shall meet NEMA 4X and IP66 enclosure ratings. (4X is used for corrosive atmospheres)

8.3.2 Enclosure Protection - Indoor Type

8.3.2.1 Shall meet NEMA12 and/or IP52 enclosure ratings.

8.3.3 Over-Pressure Relief/Enclosure Vent

8.3.3.1 Over-pressure relief for enclosures shall be incorporated in the event of internal pressurization of an enclosure either by leakage of sampled material or other pressurization means.

△ 8.3.4 Heating and Control

8.3.4.1 Heating of typical enclosures shall be done to maintain the environment temperature between 10 and 60 C. Special high temperature systems may require heating up to 120 C.

8.3.4.2 Purpose of the enclosure heating is to assist the substrate heater during colder operating cycles and also provide a controlled environment for equipment operation. To maintain heat efficiency it is recommended that the enclosure be insulated.

8.3.4.3 Heating shall be accomplished by means of a Division/Zone 1 style commercial Ex d heater.

8.3.4.4 An intrinsically safe temperature sensor, controlled by the SAM module, which ties into the NeSSI-bus, shall monitor the enclosure environment temperature.

8.3.4.5 Temperature control shall be ± 2 C.

8.3.4.6 A solid state relay (SSR) shall modulate the heater

8.3.4.6.1 The SSR shall connect to the NeSSI-bus and SAM.

8.3.4.7 An optional connectivity solution (supervisory/remote control) shall be by the use of the l**ocal** wireless connection to the SAM. (Since external power must be provided for the heater, power provided by a NeSSI-bus connection may not be required.)

8.3.4.8 Consideration should be given to a Div/Zone 1 air bath heating and control system for high temperature systems.

8.3.5 Electrical Penetrations

8.3.5.1 AC power shall enter the enclosure through an electrical hub or IEC cable gland

8.3.6 Tubing Penetrations

8.3.6.1 Tube penetrations shall be through bulkheads.

8.3.7 Heat Traced Sample Tube Penetrations

8.3.7.1 Penetrations shall be accomplished by means of commercial heat tracing bulkhead glands.

8.3.8 Substrate Mounting

8.3.8.1 Allows back-plate (vertical) as well as horizontal mounting.

8.3.9 Enclosure Materials of Construction

8.3.9.1 Fiberglass, painted steel or stainless steel.

△ 8.3.10 Power Source

8.3.10.1 Voltage: 100 to 120 VAC and/or 225 to 250 VAC @ 50/60 Hz (universal power).

△ 8.3.11 Enclosure Design

8.3.11.1 A clamshell configuration shall be considered for smaller applications.

8.3.11.2 A rectangular enclosure shall be considered for larger applications.

8.3.11.3 A tempered glass window shall be provided for systems with local indicators.

8.3.11.4 Consideration should be given to design of a modular microClimate enclosure with snap out panels to allow the insertion of heat tracer glands, tubing bulkheads, enclosure bulkhead to substrate connectors, electrical connectors. This would eliminate the need for drilling, custom assembly or special tools or skills for assembly.

8.3.11.5 Consideration should be given to the provision of custom specified tagging as part of the enclosure package.

△ 8.3.12 Auxiliary Heat Tracing Control and Monitoring

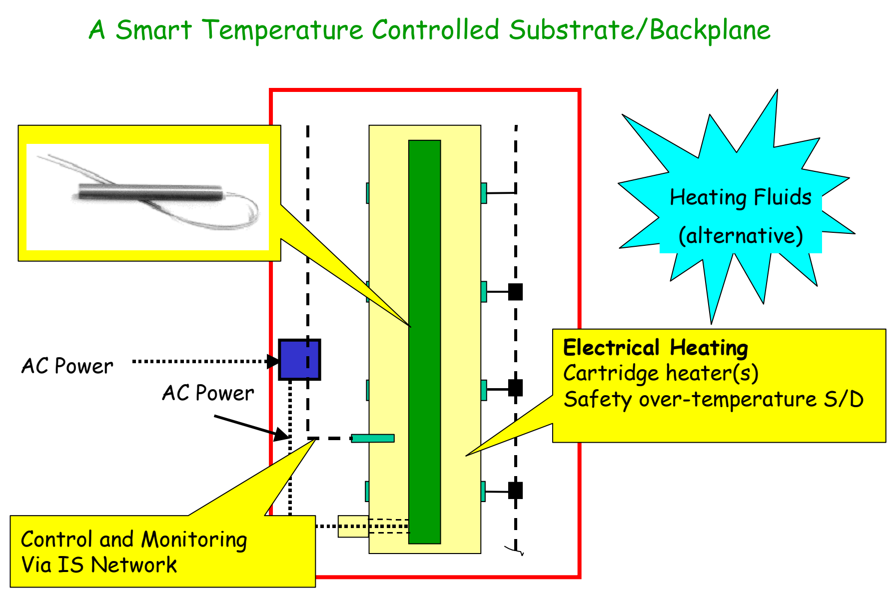
8.2.12.1 Consideration shall be made to monitor and control two heat tracing circuits from the SAM.

9.0 SUBSTRATE HEATING

△ ### *9.1 Purpose*

The substrate is heated to maintain the substrate (base), the process wetted sensors/actuator transducers as well as the process wetted passive component (e.g. filters) at a temperature above the sample dewpoint temperature for gases and below the bubble point temperature for liquid applications. Additionally a constant temperature on the substrate stabilizes the sensor measuring environment and enhances equipment performance. This will be especially useful for microReactor and microAnalytical (Gen III) equipped systems which may require additional zone heating requirements. Additionally, substrate heating can be used to facilitate the use of on-substrate permeation type calibration devices which are temperature (and flow) dependant. It is not the intent to control the substrate by means of completely heating the enclosure. This is not energy efficient. Enclosure heating is done as a supplementary conditioning method. Refer to Figure 9 for a substrate heating technique. Steam, glycol or other heating methods are less desirable due to higher long term cost of ownership issues such as maintenance costs, plugging, cleaning, and poor efficiencies. Under some circumstances substrate cooling may be required. This could potentially be done with Peltier style cooling, however this is not covered by the NeSSI Gen II specification at this time.

Figure 9. Substrate Heater



9.2 Substrate Heater and Temperature Transducer

9.2.1 Heating Method

9.2.1.1 "Pencil" style encapsulated heaters inserted into the substrate or an equivalent such as heat tape, heating pad, heat pipe, thermoelectric heater, etc.

9.2.1.2 "Pencil" or equivalent heating elements may be a preferential heating method for the substrate components. The heating elements shall be inserted or incorporated into the substrate mounting plate (back-panel/pan). Adequate heat conduction shall be considered before using this method.

9.2.2 Heating Range

9.2.2.1 Shall be controllable over the range of 10 to 120 C (+/- 0.25 C. control accuracy).

△ 9.2.3 Measurement and Control (The "Smart" Heater Concept)

9.2.3.1 A substrate mounted (inserted) intrinsically safe temperature sensor (e.g. RTD) shall be employed and preferentially embedded in the heater.

9.2.3.2 Temperature sensor and control solid state relay shall connect to multi-drop serial bus

9.2.3.3 Heater solid state relay (SSR) shall be embedded in the heater Ex d condulet/connection.

9.2.3.4 An optional connectivity solution (supervisory/remote control) shall be by the use of the **local** wireless connection to the SAM. (Since external power must be provided for this heater, power provided by a NeSSI-bus connection may not be required.)

△ 9.2.4 Power Source

9.2.4.1 Voltage: 100 to 120 VAC and/or 225 to 250 VAC @ 50/60 Hz [universal power]

9.2.5 Electrical Connection

9.2.5.1 A conduit entry hub (or IEC cable gland) shall be used to connect to the substrate heater block.

9.2.6 Over-Temperature Cut-off

9.2.6.1 An embedded over-temperature power cut-off thermostat or dual redundant temperature sensor and independent shut-off device shall be incorporated into any device whose normal or failure mode allows the surface temperature of the heater to exceed the T4-rating allowable temperature. The device shall meet all regulating agency criteria for number of operations before failure.

△ 9.2.7 Certification

9.2.7.1 The heater shall meet Ex d certification

9.2.7.2 The temperature sensor, solid state relay (SSR) control signal and connecting wiring shall be Ex ib (optional Ex ia) certified. Appropriate separation will be required between heating (power) circuits and IS wiring.

10.0 INTRINSICALLY SAFE SENSOR/ACTUATOR SERIAL BUS

10.1 Number of Transducers (Sensors and Actuators)

△ Based on a IEC Class II**B** hazardous rating, the intrinsically safe (IS) NeSSI-bus shall, as a minimum, be able to handle no less than 25 transducer (sensors and/or actuators) in any combination as a "standard" configuration using one IS NeSSI-bus port. An "intense" system (a SAM with 2 Nessi-bus ports each with their own IS isolation barrier) shall be capable of handling up to 50 low power IS transducer/nodes in any combination. An **"**intense**"** system would be one with multiple streams or multiple analytical systems. Conceptual guidelines to extend the number of nodes beyond 128 shall be provided (e.g. the potential use of a third port). As an alternative, to handle the special case of a high current draw device such as an analytical sensor, the 2nd channel may be reserved exclusively for this device with a separate isolation barrier and power supply. Higher node counts can be expected if the installation does not require intrinsic safety barriers. (e.g. for use in non-hazardous electrical environments.) Lower node counts can be expected for the more stringent IEC Class IIC (hydrogen, acetylene) environment. In order to accommodate the maximum number of nodes the transducer (sensors and actuators) power requirements need to be minimized.

△ *10.2 Purpose of a Multi-Drop Serial Bus*

To maximize the diagnostic benefits of a smart digital sensor/actuator transducer, the implementation of a Sensor/Actuator serial multi-drop bus such as NeSSI-bus (as opposed to the traditional 4 -20 mA interfaces) is required to allow transmission not only of the sensor data in engineering units, but also status and diagnostic information associated with each sensor/actuator. The availability of special status and diagnostic information is expected to optimize maintenance efficiency, hence reduction in the cost of ownership of the analyzer/sampling system. To further reduce the cost of sensors (by occupying only one substrate block), it is expected that some sensors may be able to measure more than one physical property. For example, binary sensors can measure two properties such as pressure/temp or flow/temperature; a micro-coriolis sensor would be an example of a ternary sensor, measuring density, mass flow and temperature. The NeSSI-bus protocol shall, therefore, allow for the transmission of multiple data elements between the individual sensor/actuators and the host controller.

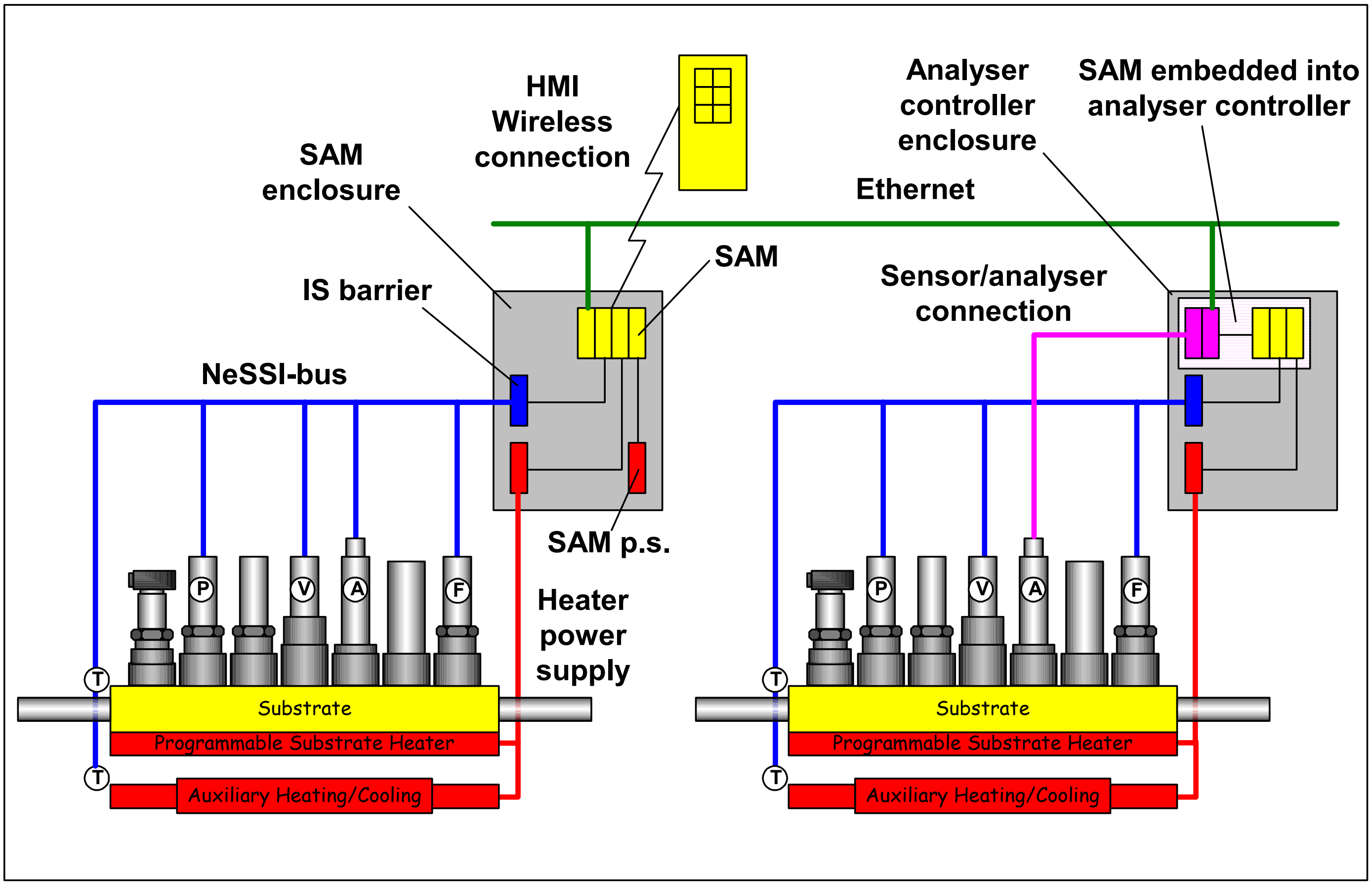
In addition, an intrinsically safe sensor bus is preferred to avoid any wiring connections or disconnection during "plug and play" swapping of sensors and actuators on any substrate position. Using intrinsically safe cables/connectors allows for live connections and disconnection in hazardous areas without danger of explosion or the need for a gas test and a safe work permit. Additional savings will be realized by eliminating the need for conduit, condulets and conduit/cable seals and glands.

△ *10.3 NeSSI-bus Requirements*

The Process Analytics market is relatively small and to make the development of smart NeSSI sensors/actuators economically feasible, the goal is to select one NeSSI-bus technology to maximize the commonality of the initial offering of sensors and actuators. It is very important that the commonality of the NeSSI-bus components up to the IS barriers and power supply are maintained to ensure the application of the same NeSSI and NeSSI-bus technology, whether the host controller is stand-alone (i.e. SAM) or embedded with the analyzer controller (see Fig. 10). Based on the requirements outlined in Section 10.4 below, a survey of industrial serial communication was performed to identify potential IS candidates meeting the NeSSI Sensor/actuator footprint requirements such as Foundation Fieldbus, ControlNet, LONworks, etc**.** For the DOE contract ProfiBus will be used**.** CANbus currently meets the NeSSI sensor/actuator footprint requirements but it has not been certified as Intrinsically Safe as of yet. Initial tests indicate that by limiting distance and speed, there is no reason why CANbus cannot accommodate an IS version for certification. If CANbus achieves intrinsically safe certification, then several CANbus protocols are available such as DeviceNet, CANOpen etc.

△

Figure 10. Stand-alone and Embedded SAM



Stand-alone SAM

- SAM has its own enclosure
- The NeSSI-bus provides intrinsically safe, bi-directional communication with sensors and actuators
- Heating for the substrate, enclosure or other devices is controlled by SAM
- SAM communicates to the DCS and operations and maintenance domains via Ethernet.

Embedded SAM

- The sensor or analyzer has its own controller and is directly connected to the controller, for example:
  - pH sensor connected with electrode cable
  - spectrometer with a sample cell on the substrate connected by fiber optic cable
  - GC with the sample delivered by NeSSI
- SAM is embedded into the analyzer controller
- The NeSSI-bus provides intrinsically safe, bi-directional communication with sensors and actuators
- Heating for the substrate, enclosure or other devices is controlled by SAM
- Analyzer controller communicates to the DCS and operations and maintenance domains via Ethernet.

△ *10.4 NeSSI-Bus Design Considerations*

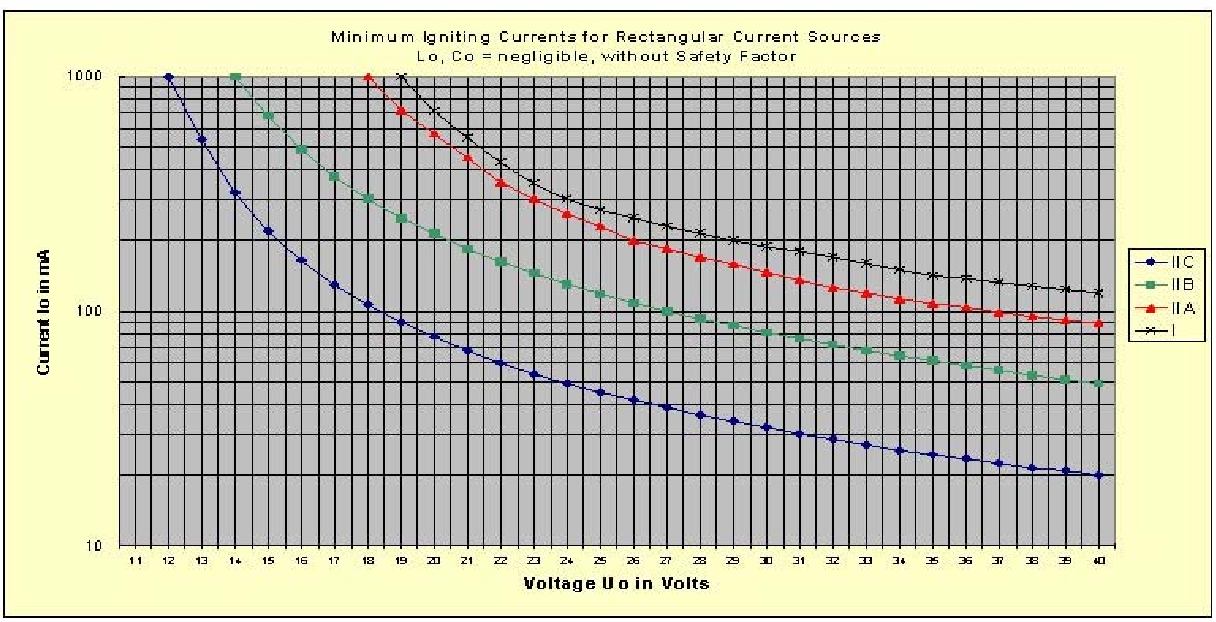
As an intrinsically safe operations environment basically limits the available power, careful consideration shall be given to the power requirements for the sensors/actuators (transducers) and the associated NeSSI-bus communication components. The primary goal shall be to maximize the number of nodes (i.e. sensor/actuator devices) that can be supported on the NeSSI-bus by taking advantage of state-of-the-art low power NeSSI-bus devices and designs. Consideration shall therefore be given to the use of low-power transducers and integrated signal conditioners, NeSSI-bus micro-controllers with integrated A/D and transceiver components based on the new generation of 3.3V CMOS technology. Another option to increase the number of supported intrinsically safe devices on the NeSSI substrate, is to configure SAM with two NeSSI-bus ports. The second NeSSI-bus will have its own independent power supply and IS barrier.

As a minimum, the intrinsically safe NeSSI-bus design shall meet Ex ib (optional Ex ia) requirements according to EN50020 or IEC 79-11. The design and packaging of the actuator transducer, sensor transducers, and integrated signal conditioning, NeSSI-bus micro-controller, A/D and transceiver components shall be segmented into self-contained entities. IS certification of the overall bus and associated communication components shall be based on these entities to allow replacement of entity modules without requiring re-certification. In order to increase the number of devices which can be supported on the IS Bus, the alternative FISCO (Fieldbus Intrinsically Safe Concept) Model shall be evaluated as the basis for designing and connecting the NeSSI IS bus and components.

Special considerations shall be given to IS design and certification to the two gas groups IIC (hydrogen, acetylene) and IIB (most other hazardous gases) as the latter group can accommodate more power on the NeSSI-bus. NeSSI components shall require certifications for both IIC and IIB industrial atmospheres. Figure 11 [12] illustrates the safe operating region for intrinsic safety.

Figure 11. Intrinsically Safe Operating Region

△



[12] Courtesy of Dr. U. Johannsmeyer, PTB, from IEC Subcommittee SC31G

At this time, it is anticipated that IS implementation shall be based on the use of IS galvanic isolation barriers. Consideration to use NeSSI-bus mini-connectors and the capacity to connect to any number of NeSSI-bus devices.

Encapsulation (Ex m) of the NeSSI-bus components in the transducer housing shall also be considered as an adjunct path (with intrinsic safety) to meet Zone 1 requirements.

Power supplies and IS barriers for the NeSSI-bus components, sensors and barriers shall be located in the same explosion proof (Ex d) enclosure as the host controller, whether stand-alone (i.e. SAM) or embedded. To minimize the space requirements in the enclosure, miniature power supplies shall be used to power the IS barriers/bus/device components and sensors [13]. Consideration shall be given to incorporating the intrinsically safe barrier electronics into the actual SAM controller. The nominal power supply input voltage shall be chosen such to minimize the size of the power supplies yet meet the requirements of the appropriate IS standard to which the system will be certified.

△

10.5 NeSSI-bus requirements

The following requirements for the selection of Level 1 NeSSI-bus and Communications components were used to select IS NeSSI-bus:

10.5.1 General NeSSI-bus Requirements

- 10.5.1.1 The NeSSI-bus technology, physical layer and higher level protocols shall be based on an open, i.e. non-proprietary standard
- 10.5.1.2 If not yet certified, supplier(s) shall demonstrate operation of the NeSSI-bus under IS configuration
- 10.5.1.3 The NeSSI-bus shall be supported by an industry group who has ownership of the standard and a means for testing compliance with the standard
- 10.5.1.4 Technical and application development support shall be available in the form of readily available development tools
- 10.5.1.5 Multiple suppliers of the NeSSI-bus components shall be available.
- 10.5.1.6 Low cost, compact chip set with large installed base.

10.5.2 IS Requirements and Other Safety Requirements

- 10.5.2.1 Intrinsically Safe requirements as per paragraph "IS Bus Design Considerations" above
- 10.5.2.2. The nominal T-rating for the sensor and NeSSI-bus components shall be T4, i.e. 135 C

10.5.3 Packaging and Physical Attributes

- 10.5.3.1 Physical size of the NeSSI-bus transducers shall be such that the complete package (including transducers, signal conditioning A/D, micro-controller, transceiver components) shall fit the dimensions of approximately 1".
- 10.5.3.2 Miniature size connectors on sensors/actuators shall use daisy chain connectors integral to the cable to avoid dual connectors on a transducer and to allow easy configuration as serial (trunk) or star connections.
- 10.5.3.3 The NeSSI-bus cable and connectors shall be designed such that any sensor/actuator can be moved to any position on the substrate without the need to replace the "backbone" cable (replacement of short cable segments is acceptable).
- 10.5.3.4 Typical maximums for various cable lengths and transmission speeds for the chosen NeSSI-bus shall be supplied.

[13] A single, low voltage power supply such as 12 VDC reduces the package size and packaging costs and complexity.

10.5.3.5 The Host controller shall support an additional NeSSI-bus port; this second NeSSI-bus shall be configured and certified independently from the first NeSSI-bus.

10.5.3.6 IS cabling shall be blue in color. (industry common practice)

△ 10.5.4 Configuration and Measurement Requirements

10.5.4.1 Where appropriate, the personality of the device micro-controllers shall be configurable to support potentially more than one High Level Protocol (HLP) but only one per NeSSI-bus, by flashing its memory from the host controller (it is important to note that the goal is to preserve a common hardware platform for the sensor devices but where appropriate and desirable, allow the supplier to use software tools to configure his sensors with a specific HLP).

10.5.4.2 Each device shall be configured at the time of manufacture with Engineering Design Sheet - EDS; (or alternatively TEDS for due consideration and possible future implementation of the IEEE 1451.6 emerging standard.) A copy of the EDS shall be maintained on the Host controller. Alternatively, the equivalent of the IEEE 1451.6 TEDS shall be configurable on the Host controller for each remote NeSSI-bus device. In either case, the Host controller (stand-alone or embedded) shall be able to download all EDS/TEDS and other supplementary configuration parameters into the sensor micro-controller. (Note that the user interface which allows viewing, editing, downloading of configuration tables on the Host Controller can be a remote workstation, a PDA linked wirelessly to the Host Controller or in the case of an embedded Host Controller, via the user interface associated with its analyzer controller).

10.5.4.3 The Host controller shall be able to perform "plug-and-play" functions like automatically sensing when a device is added to the bus, downloading configuration data (if necessary), initializing the device and starting the measurement cycle.

10.5.4.4 The integrated NeSSI-bus device A/D shall be configured to read multiple sensor transducer outputs, whether they are related to one or more sensors proper or to a diagnostic physical measurement.

10.5.4.5 The NeSSI-bus device shall transmit status and data in engineering units; alternatively, the host controller shall convert native sensor data into engineering units. The native data shall be visible to any remote workstation/controller. The NeSSI-bus (unless specially configured to handle) is not intended to be the communication channel for high-intensity data such as raw chromatograms and spectra.

10.5.4.6 The supplier of each sensor shall consider designing into the sensor any diagnostic information which will allow the validation of the sensor operation e.g., failure of the sensor electronics, increased transducer noise, etc.

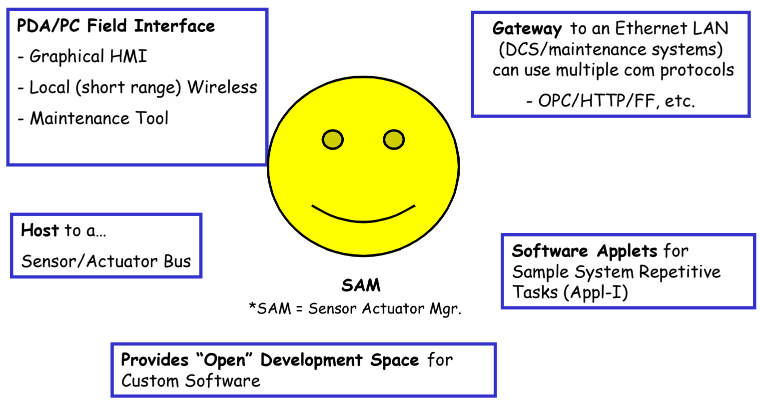
11.0 SENSOR ACTUATOR MANAGER (SAM)

11.1 SAM General Requirements

△

Refer to Figure 12 for a recap of SAM's functions.

Figure 12. Recap of SAM Functions



11.2 Integrated Hardware Components

11.2.1 SAM shall be a microcomputer, power supply(s), intrinsically safe barrier(s) and one or more integrated communication channels all mounted in an Ex d condulet. SAM shall be packaged to minimize the size of the condulet but without impeding the ability to remove and replace serviceable components or the whole unit during maintenance.
Alternatively the SAM and power supply may, for Div/Zone 2 areas, be rated and packaged together as Ex n (non-incendive). However the IS isolator or barrier associated with this SAM and power supply shall be packaged in a stand-alone Ex d flameproof condulet.

△

11.2.2 Communication channels shall include:

11.2.2.1 two NeSSI-bus network ports, each with its own IS barrier, network micro-controller and transceiver, and each capable of supporting 12-25 transducers. The Nessi-bus shall use an existing communication standard (e.g. ProfiBus, CANBUS, etc.) or a subset of such a standard. IS certification shall be provided for the network wiring and associated IS sensors/actuators associated with the Ex ib (optional Ex ia) NeSSI-bus front-end. A wiring system which enables simple plus-in plug-out connections shall be used. (Specifically conduit systems or armored cables shall not be used.)

11.2.2.2 two "hardwired" Ethernet ports (for redundant remote connectivity to a DCS, Operator/Maintenance station or off-substrate "smart" analyzer). Connection may be by copper or fibre optic. (Gen III may have Ethernet wireless option)

11.2.2.3 one wireless port (e.g. Bluetooth), to connect to a "local" short range, field portable (preferably IS or Zone/Div 2) maintenance and operating terminal device such as a PC or a PDA. (personal digital assistant)

11.2.2.4 a Zone/Div 2 minimum rated I/O module capable of receiving a minimum of 8 analogue (4-20mA) and a minimum of 8 digital (dry contact) inputs (to enable connection of 'dumb' devices into the analyzer system); and driving a minimum of 8 analogue outputs (4-20mA isolated) and a minimum of 8 digital outputs (dry contacts) (for connection to traditional data using devices or to provide a route for legacy analyzer systems). An additional Junction box may be included to provide physical space for wiring connections. Wiring to this JB may be via conduit or armoured cable.

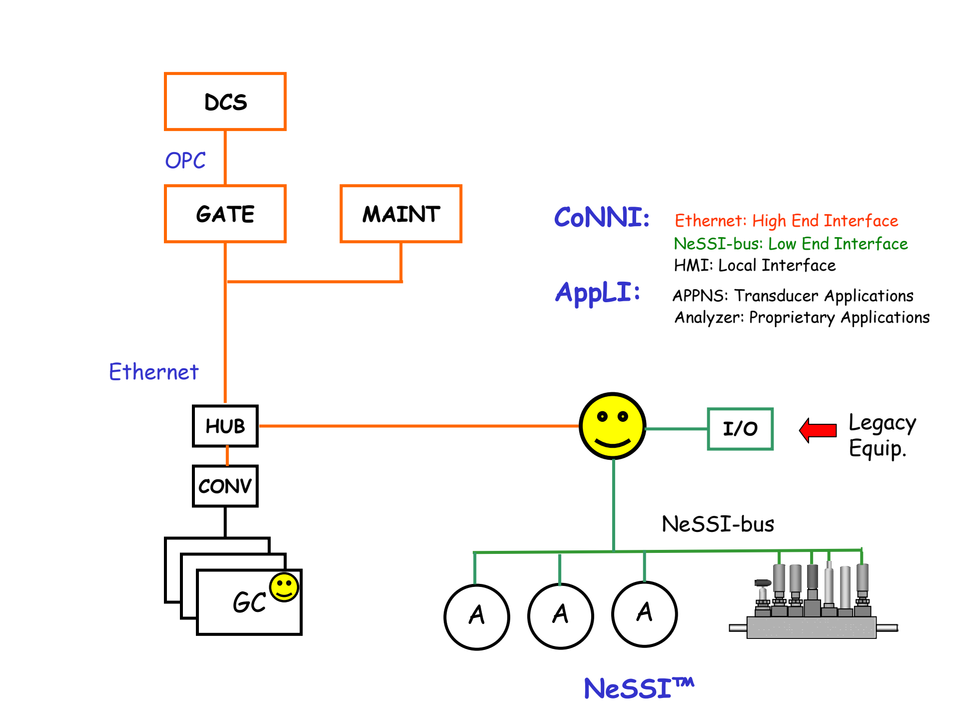
11.2.2.5 Legacy System Connectivity Options (Refer to Figure 13)

Connection to Legacy Analyzers- by means of auxiliary I/O inputs provided with the SAM (i.e. 4-20 mA concentration and status contacts) by means of Ethernet high level communication (if supported by legacy analyzer system)

Connection to Legacy (non-serial) DCS Systems - by means of auxiliary I/O outputs provided with the SAM

11.2.3 In terms of the overall communications architecture of analyzer systems, the Nessi-bus brings analyzer and sensor data to a local SAM controller. These data include results, control and status information for analyzers and sample system components.

Figure 13. Legacy Connectivity



11.3 Software Components for SAM.

SAM shall include the following software functions:

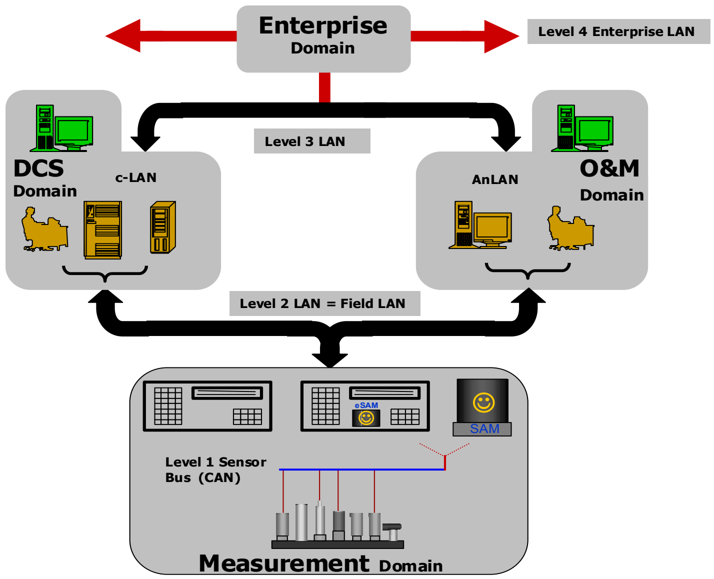
11.3.1 Communication with the microSensors via the Nessi-bus network to:
- 11.3.1.1 Read their measurement, status, diagnostic and identification.
- 11.3.1.2 Download configuration tables, identification, engineering values and/or commands to control devices.

△ 11.3.2 SAM communicates with its own Host Analyzer Controller and optional Data Server (via the Ethernet port) to:
- 11.3.2.1 continuously update it with the sensor and actuator measurement values, status and diagnostic values collected via the NeSSI-bus.
- 11.3.2.2 download and relay status, configuration tables and/or commands to devices on the NeSSI-bus.
- 11.3.2.3 Consideration shall be given to the use of OPC as the High Level Communications Protocol for data exchange between SAM, its Host Analyzer Controller and Data Server. Refer to Figure 14 which illustrates SAM's connectivity to High Level Communications.
- 11.3.2.4 It is envisioned that these data are made visible to process control systems and other data users via OPC. The OPC servers could be embedded into field devices, such as analyzers, into SAM or else into gateway devices at the control room. Communication is over Ethernet via TCP/IP addressing. In addition, access to analyzer data such as spectra chromatograms etc. is also possible using vendor specific software which also communicates (peacefully coexists) on the same Ethernet communication system. As a planning basis, assume either that the file size of a chromatogram or spectrum is of the order of 1MB and that downloading is required in 10 seconds; or for transmission of real time data, 100 bytes are transmitted 32 times per second, without significant impact on other network traffic.

11.3.3 Support for SAM resident simple applets – as a minimum, two applets shall be provided:
- 11.3.3.1 Communications monitor (to track communication statistics for each port and network device).
- 11.3.3.2 Validation monitoring and control (to track diagnostics and maintenance parameters) for each analytical system. For example PID flow control, diagnostic alarms based on system flow, pressure, temperature, etc.

11.3.4 Support for a GUI based user interface between SAM and
- 11.3.4.1 Remote Workstation via the Ethernet Port.
- 11.3.4.2 Field (local) portable Intrinsically Safe PC or PDA via the wireless port

Figure 14. Domain Architecture & SAM's Domain



11.4 Graphical User Interface (GUI) for SAM

11.4.1 Human Machine Interface (HMI) functions which shall be included as a minimum are:
- 11.4.1.1 real time viewing of all measurement, status and diagnostic data for any sensor/actuator with some limited tracking/displaying of stored data
- 11.4.1.2 viewing and editing of all configuration tables for any device on the NeSSI-bus; the configuration tables may be resident on the NeSSI-bus device or a copy may exist on SAM itself
- 11.4.1.3 execution of manual commands to run SAM diagnostics or test device operation on the NeSSI-bus
- 11.4.1.4 viewing and editing of all applet configuration, script files or applet programs
- 11.4.1.5 viewing of flow paths e.g. valve open or closed.
- 11.4.1.6 entry of set points for PID control.

11.5 SAM Software Applets

11.5.1 SAM supports resident applets - as a minimum, two applets shall be provided
- 11.5.1.1 Communications Monitor
  This applet will monitor communication statistics associated with each communications port and each device on the NeSSI-bus including but not limited to
  - 11.5.1.1.1 successful transmissions
  - 11.5.1.1.2 failed transmissions
  - 11.5.1.1.3 number of retries
- 11.5.2.1 Transducer Monitor
  This applet will monitor the following diagnostic parameters and generate a warning or error flag where appropriate:
  - 11.5.2.1.1 any inherent diagnostic flags associated with each device on the NeSSI-bus
  - 11.5.2.1.2 measurement and rate of change limits associated with each transducer
  - 11.5.2.1.3 pressure drop across filters where individual p-sensors are provided

11.5.2.1.4 the total number of actuations for each actuator and compared against an upper limit (limits shall be set as part of configuration tables)

11.5.3.1 System Health Monitoring
- 11.5.3.1.1 sample flow OK
- 11.5.3.1.2 bypass flow OK
- 11.5.3.1.3 inlet pressure OK
- 11.5.3.1.4 outlet pressure OK
- 11.5.3.1.5 enclosure temperature OK
- 11.5.3.1.6 substrate temperature OK
- 11.5.3.1.7 utilities OK

11.5.4.1 Traffic Light Status Communication (See Figure 15)
This applet will provide common fault, warn (predictive) and validation alarms for System Health Monitoring to a DCS.

11.5.5.1 Zero and Span Check Validation
- 11.4.5.1.1 actuate zero valve and check if within high and low limits
- 11.4.5.1.2 actuate span valve and check if within high and low limits

11.6 Some Typical Diagnostic and Control I/O for the NeSSI-bus may include: (for reference)

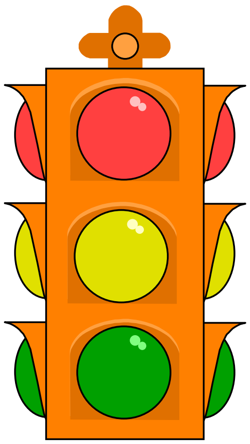
11.6.1 Inputs
- temperature sensor
- substrate sensor
- inlet pressure
- outlet pressure
- sample flow
- bypass flow
- utility pressure(s)
- analytical value
- analytical diagnostic e.g. Fault Alarm

11.6.2 Outputs
- enclosure temperature SSR
- substrate temperature SSR
- inlet pressure to valve
- pressure to valve
- sample flow to valve
- bypass flow to valve

11.7 SAM AC Power

11.7.1 120/240 VAC 50/60 Hz Universal Power

Figure 15. Simple Traffic Light Analogy for Communicating of Health Status to a D.C.S.



- **Is Data Good or Bad?**
When ON my data is BAD and when OFF my data is GOOD

- **Is There a Problem?**
Please get help. (When ON my data is still GOOD but I need attention soon.)

- **In Process or Validation Mode?**
When ON=Process Fluid is in the substrate. When OFF=Validation Fluid or Check in progress.

12.0 ADVANCED APPLICATIONS (APPL-I)

12.1 Purpose

Advanced applications (Appl-I) shall provide a standard suite of "pick-list" functions, which can control/monitor a miniature, modular or applets sample system. End Users will have the choice of purchasing a combination of different functions in order to build a sample system without being "locked" into a proprietary solution. The design objectives of a smart sampling system are to:

12.1.1 Provide a representative sample to the analytical sensor(s) and validate under all process conditions
12.1.2 Integrate the sample system with the analytical and other diagnostic sensors
12.1.2 Standardize analytical systems configuration and operation by providing "smart" sample system applets
12.1.3 Increase the reliability of analyzer sample systems
12.1.4 Eliminate to an absolute minimum routine maintenance (replace with predictive maintenance)
12.1.5 Utilize a portable computer language such as Java, Active-x, to write applets, in order to use across platforms

12.2 What is a Smart Sampling System?

12.2.1 Is capable of doing self-adjustment for optimal performance under variable process conditions
12.2.2 Tracks reliability and operation metrics
12.2.3 Provides an intuitive self-diagnostic GUI (graphical user interface) accessible from peer devices (PDA's etc.) or higher level devices such as workstations
12.2.4 Acts as a host to one or more analyzer controllers (status and control information) in a stand-alone mode or may be embedded in an analyzer controller

12.3 Self-adjusting and standard operating "Applets" [14]

[14] Some of these functions may be available in Analyzer Controllers.

△ 12.3.1 Applet Functions

12.3.1.1 Pressure control by means of a pressure sensor / control valve
12.3.1.2 Flow control to maintain a constant flow by using a flow sensor / control valve
12.3.1.3 Pressure control around a fluctuating process control valve to maintain a constant flow
12.3.1.4 Pressure controls for atmospheric pressure or to provide a fixed pressure on the inlet or outlet of an analytical sensor
12.3.1.5 Temperature control of vaporizer, sample system (substrate) heater, enclosure heater, instrument air purifiers, etc.
12.3.1.6 Swings sample filters based on DP or change / loss of flow
12.3.1.7 Self-purges / cleans a dirty system on an as need or regular basis
12.3.1.8 Swings gas cylinders based on pressures
12.3.1.9 Provides safety trips - pressure, temperature, flow (leak), etc.
12.3.1.10 Shuts off the sampling system / analysis when the process stream is taken out of service
12.3.1.11 Analytical interaction modules - ranges, optical filter selection, path length selection
12.3.1.12 "Soft" startup and shutdown after process events
12.3.1.13 Stream switching
12.3.1.14 Valve actuation counter and required service flag based on number of actuations
12.3.1.15 Reagent consumption counter and service flag to notify the need to replenish
12.3.1.16 Barometric pressure sensing for any compensation algorithm
12.3.1.17 Leak detection by means of pressure lock-in and monitoring for pressure loss.
12.3.1.18 Heat tracer control.
12.3.1.19 Control of sample pumping and aspiration systems.
12.3.1.20 Self-validation (auto benchmarking)
12.3.1.21 System health monitoring (appropriate P, T and F of all sub-systems)
12.3.1.22 Intelligent diagnostics, such as automatic detection of deviation from historical behavior, based on statistical or other tests.
12.3.1.23 Benchmark capability including statistical tools (SQC) to determine the need for calibration.

12.4 Track Reliability and Operations Metrics

12.4.1 Reliability and Operation Functions…

12.4.1.1 Calculates cycles, for example:
- valve operations (millions of ops)
- filter in service time (days)

12.4.1.2 Tabulates consumption/use of:
- sample fluid
- utility gases e.g. helium, nitrogen, instrument air
- calibration gases
- power usage

12.4.1.3 Tracks temperature, pressure, flow cycles or patterns
12.4.1.4 Provides statistics on percent uptime
12.4.1.5 Provides drift information on all parameters
12.4.1.6 Tracks control chart for zero / span benchmark
12.4.1.7 Tracks control chart for zero / span calibration
12.4.1.8 Provides a maintenance log
12.4.1.9 Data storage and recovery (e.g. CEMS applications)
12.4.1.10 Equipment data e.g. serial number, software version, etc.
12.4.1.11 Spare parts lists
12.4.1.12 Equipment parts lists
12.4.1.13 Auto reorder points for consumable parts, gases, etc.

12.4.1.14 Generates a maintenance flag based on above functions and known service intervals.

13.0 ANALYTICAL SENSORS

13.1 Background

Miniature analytical sensors based on micro-machined fabrication techniques and MEMS technology are now coming to market. Currently there are several developers building analytical sensors designed for substrate mounting. Ideally one sensor could scan the sample and report the concentrations, however on a more practical note; many sensors could be component specific and be assembled to accomplish the analysis. Figure 16 defines how analytical sensors could tie into the overall system. The same figure also outlines how both scanning and component specific analytical sensors can be integrated. For simple sensors SAM could handle the processing requirements. For more complex analytical devices, a separate Analytical Transmitter could do processing.

There are already several analytical devices, which fit on the substrate. These include pH, conductivity, oxygen, moisture and UV/VIS. Many more will become available as this technology matures. Table 5 provides a "shopping list" of potential "designer" microAnalytical devices which could be candidates for a NeSSI Generation III system.

Figure 16. Analytical Sensors on the Substrate

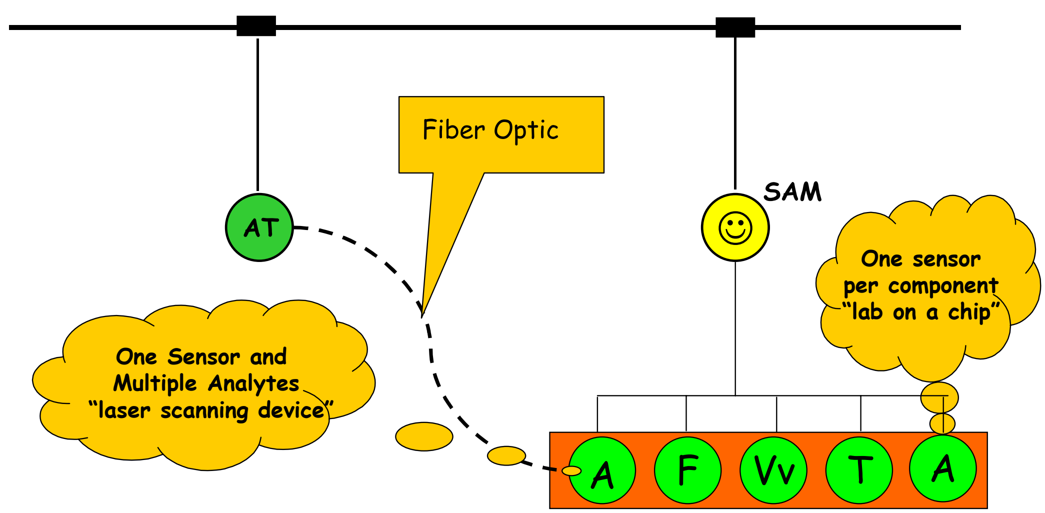


Table 5. Potential Miniature Analytical Sensors (short list)

Application	Ranges	Notes
Single Analyte/Parameter		
Moisture in gases/vapours	0-1 PPM; 0-10 PPM; 0-100 PPM v/v	Gas
Moisture in liquids	0-10 PPM w/w; 0-100 PPM w/w	Liquid
Oxygen	0-1 PPM; 1-10 PPM; 0-100 PPM; 0-1%; 0-25%; 0-100%	Gas
Mini pH		Liquid
Dissolved oxygen		Liquid
Conductivity		Liquid
ORP		Liquid
Hydrogen	PPM, high and low percent	Gas
Sulphur	PPM; PPB	Gas
Cations and Anions e.g. Sodium		Liquid
Silica		Liquid
LEL	0-100 % LEL	Gas
CO	PPM	Gas
CO2	%	Gas
NOx	PPM	Gas
SOx	PPM	Gas
Electrochemical sensors		component specific
Multi-Analyte/Parameter		
Miniature spectrometers (optical)		Includes UV, VIS, IR, NIR, TDL and Raman - (dispersive)
Miniature mass spectrometers		Time of Flight, others…
Gas chromatograph		
Liquid chromatography		
Physical Properties		
Density		
Viscosity		

14.0 GENERATION II PROTOTYPE

△

14.1 Full featured candidate prototypes (refer to Figures 17A & 17B) shall be built to demonstrate the following Gen II elements and associated functions.

- flow sensors (sample and bypass)
- temperature sensors (microClimate enclosure, substrate block and flowing sample)
- pressure sensors (upstream pressure, downstream pressure, and utility pressure)
- "combi" on/off actuators/valves (zero, span, process)
- "combi" modulating actuator/valves for both flow and pressure control (PID loops)
- dual process stream
- zero and span calibration streams
- "control loops" for P, T, F control
- up to 25 multi-drop transducer nodes
- SAM
- absolute back-pressure control
- atmospheric pressure reference for gas chromatography

Figure 17a. NeSSI Gen II Prototype Candidate (cont. on 17b)

△

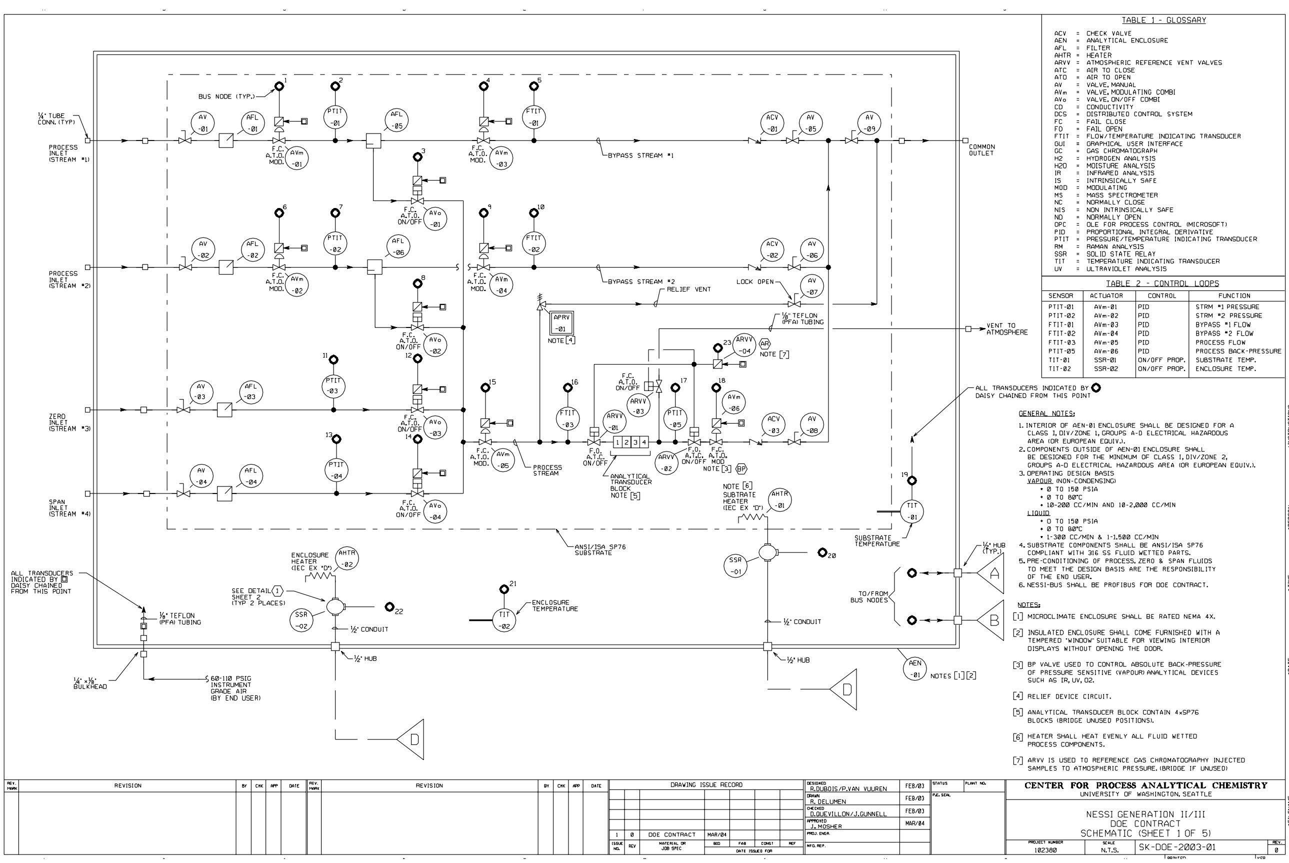
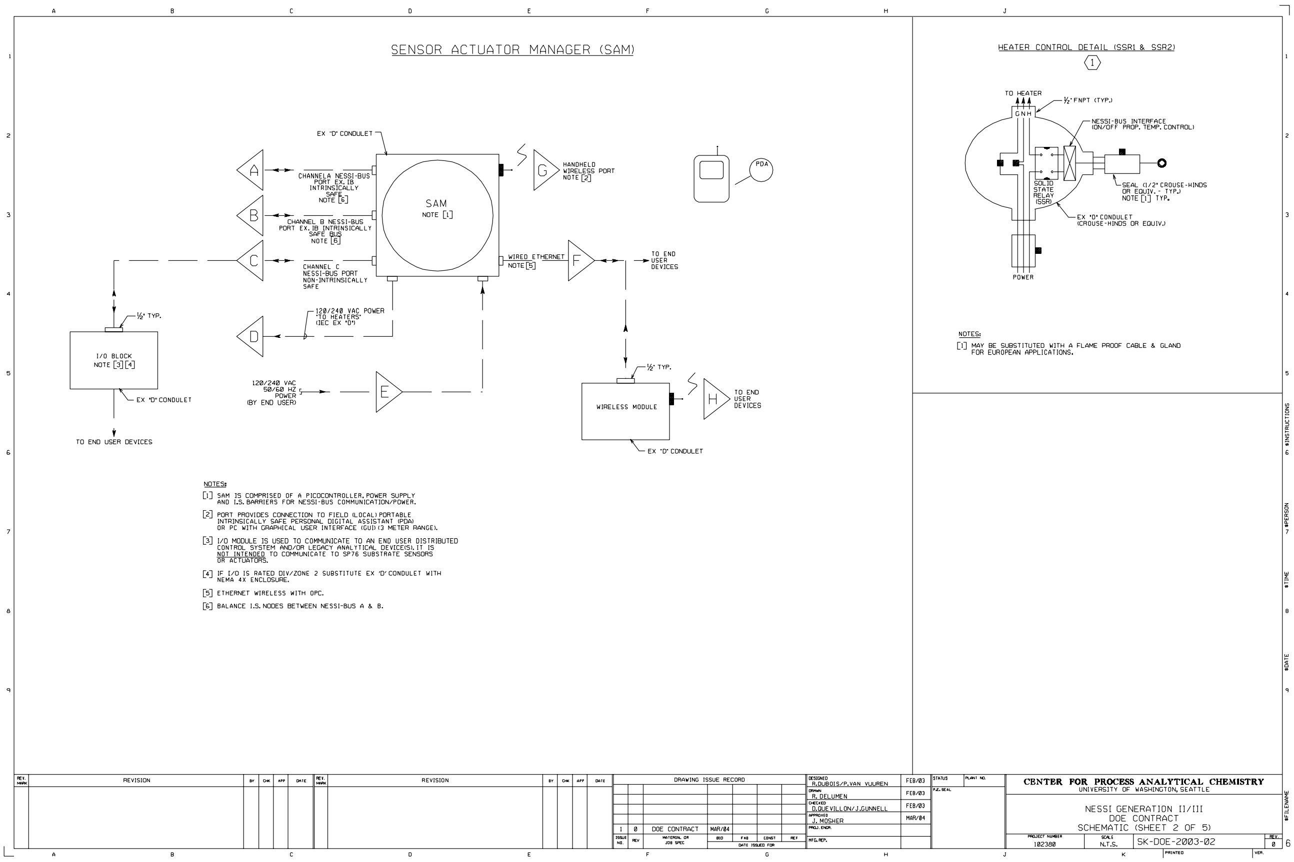


Figure 17b. NeSSI Gen II Prototype Candidate (cont. from 17a)



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15.0 SUMMARY

This conceptual and functional specification provides the requirements to build a Generation II NeSSI "electrified" miniature, modular and smart analytical system complete with diagnostic sensors and on-board sensor/actuator transducers suitable for electrically hazardous industrial environments. This Generation II design shall serve as a platform for the emerging class of miniature analytical sensors and industrially hardened wireless systems which are defined as Generation III.

The authors would like to thank the many people – too numerous to mention - who have contributed to the preparation and review of this specification. Special thanks need to be extended to Jim Tatera (Tatera and Associates) for his work with the X-team; Bob Nickels, John Mosher, Ulrich Bonne (Honeywell); Rick Ales (Swagelok); and Danny Quevillon and Reg Hartwig (Dow Chemical).

16.0 GLOSSARY OF ACRONYMS AND DEFINITIONS

Appl-I = Application Initiative
ATEX = Atmospheres Explosives
CANbus = Controller Area Network Bus
CEC = Canadian Electrical Code
CSA = Canadian Standards Association
CE = Conformity European
CEMS = Continuous Emission Monitoring Systems
CENELEC = European Committee for Electrotechnical Standardization
Combi Valve = Combination of an IS Solenoid Pilot with a Pneumatic Valve
CPAC = The Center for Process Analytical Chemistry (University of Washington)
CPACT = The Center for Process Analytical Chemistry and Technology (U.K.)
ConnI = Connectivity Initiative (CPAC)
DCS = Distributed Control System
DoE-OIT = Department of Energy – Office of Industrial Technology
EDS = Engineering Data Sheet
F= Flow Sensor
FISCO = Fieldbus Intrinsically Safe Concept
FM = Factory Mutual
GC = Gas Chromatograph
GUI = Graphical User Interface
HLP = High Level Protocol
HMI = Human Machine Interface
IEC = International Electrotechnical Commission
IEEE = Institute of Electrical & Electronic Engineers
IR = Infrared
IS = Intrinsically Safe
ISA = The Instrumentation, Systems and Automation Society
OLE = Object Linking and Embedding
OPC = OLE for Process Control
MEMS = Micro Electrical Mechanical Systems
NEC = National Electrical Code (USA)
NeSSI™ = New Sampling/Sensor Initiative
NIR = Near Infrared
NFPA = National Fire Protection Act
NRE = Non-Recurring Engineering
P = Pressure Sensor
PC = Personal Computer
PDA = Personal Digital Assistant
PID = Proportional, Integral, Derivative (Control Algorithms)
PLC = Programmable Logic Controller
PTB = Physikalisch Technische Bundesanstalt
SAM = Sensor Actuator Manager
SS = Sample System
T = Temperature
TEDS = Transducer Electronic Data Sheet
Transducer = Sensor or Actuator
UL = Underwriter's Laboratory
Vm = Valve, modulating
Vo = Valve, on/off

△

17.0 REFERENCES

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18.0 APPENDIX 1. NESSI SENSORS CTQ - "CRITICAL TO QUALITY" FACTORS

Note: Appendix 1 is based on an interaction between Bob Nickels of Honeywell and NeSSI Gen II specification writers. NgII in the text reflects view point of Gen II specification writers.

Observations from Design for Six Sigma Growth training:

- "Vital Few" attributes which have most direct influence on quality
- Product functionality accounts for at most 40% of the buying decision

The purpose of the NeSSI Generation II specification is "integrating electrical components such as sensors and actuators (collectively referred to as transducers) onto the substrate in a manner suitable for use in electrically hazardous areas commonly found in petrochemical, refining and chemical facilities." However, rather than describing the "needs", the writers go well into the "how-to" of preferred technical solutions. By including certain technical solutions and excluding others, this has the effect of constraining supplier's options and potentially leading to inferior or overly costly solutions.

[NgII] *General Comments* -

- *Simply adding a networked communication system – to replace today's 4-20 mA systems but still retaining traditional protection methods, will only sustain and extend what we have today in process analytical. Providing technology, which utilizes low power for a miniature transducer sensor/actuator bus (e.g. an enabler for the use of intrinsically safe, non-protected wiring methods), will be disruptive to existing techniques. Although initially more expensive, it will supplant traditional more complex methods of protection and wiring techniques due to ease of implementation coupled with the high confidence level of safety*
- *A "how-to" specification – as opposed to needs based specification that you mention – is simply our desire to accelerate implementation (based on learning experiences) – as well as provide (yes) state-of-the-art technology to reduce costs maintaining analytical systems. We need to move away from providing a simple transducer with a basic signal output. We have learned from experience that a smart transducer is much more valuable to us in industry since it will lower maintenance costs. Case in point is the use of 4-20 mA, with the addition of the now ubiquitous HART protocol, has helped sustain this technology well beyond its natural life span.*

Honeywell's response to the Gen II draft specification is to identify the key "must have" requirements, and understanding the reasons and impact each has on the ultimate solution. [Ng2] *The reasons and impact has been expanded upon and new material added.*

[NgII] **Note:** *Based on the now recognized need to separately certify both to North American and European standards (previously the desire was to use one global certification agency), the reason to make the Division system equivalent to the Zone system is not required. Consequently there is no need to design for Zone 0 (and its only acceptable protection method (Ex ia) as part of the NeSSI Gen II specification. All references to Zone 0 and Ex ia will be struck from the NeSSI Gen II specification and any references to these have been removed in this document.*

REQUIREMENT #1. NeSSI transducers must be designed to meet Class 1, Division 1 (IEC Zone 1) requirements for Hazardous area protection (IEC gas groups IIC, IIB, IIA, I and North American gas groups A, B, C, D).

REASON: NeSSI components will often be installed in **enclosed areas** where explosive gases, vapors, or fluids can be present at any time requiring a high level of protection. [NgII] *This is especially critical in microClimate enclosures such as those proposed for NeSSI **By-Line** analysis. These enclosures will be handling hazardous fluids – and according to NFPA 496, the interior needs to be treated as equivalent as "Limited Release under Normal Conditions". [Comment: One of the key issues why electrical sensors and actuators are less prevalent in analyzer system designs is due to the difficulty and costs associated with meeting hazardous protection. Consequently many analyzer design practices have remained "frozen in time" and our businesses have not enjoyed the benefits of a smart, plug and play system. This problem has already been addressed by instrument manufacturers who have had to contend with instrument installations in climate protective enclosures with incoming "live" impulse lines. They have universally accepted Div/Zone 1 heaters and thermostats as auxiliary equipment. The methods of protections for their "large" instruments within these enclosures are either Ex d explosion proof or Ex ib intrinsically safe and sometimes both.]*

IMPACT: Many NeSSI installations (some estimates are as high as 80%) only require the less stringent Division 2 (Zone 2) requirements. [NgII] *Most analyzer houses have additional layers of protection including building air purging (i.e. so many air changes per hour) fan interlocks, explosion proof conduit wiring systems - or cable trays in Europe - and hazardous (LEL) gas detectors that add complexity to the analyzer house design. This is done since the analyzer house approaches the look of a large enclosure. Requiring* Division 1 (Zone 1) protection will [NgII] *initially* add cost and complexity to NeSSI components; however it will permit the use of simplified, smaller [Ng2] *"microClimate"* enclosures with optical windows and elastomer seals, and will eliminate the need for purging [NgII] *(including potentially hazardous inert purges)*, pressurization, and continuous dilution as well. [Ng2] *The objective of NeSSI is to enable the use of "By-Line" analysis in microclimate enclosures and move away from the Analytical House concept.*

REQUIREMENT #2. The Preferred Method of implementing this level of hazardous area protection is Intrinsic Safety (Ex ib) and/or Encapsulation (Ex m).

REASON: Intrinsic Safety (Ex ib) prevents arcing or sparks that could ignite an explosion by limiting the amount of electrical and thermal energy that is allowed in the hazardous area. [NgII] *Intrinsically safe methods are universally (European, North America, etc.) accepted for Division 1 and 2 (Zone 1 and 2) methods of protection.* Encapsulation (Ex m) provides protection in Division 1 [NgII] *and* 2 (Zone 1 and 2) areas by keeping flammable gases away from hot surfaces [Ng2] *and isolating any arcing or sparking devices. (e.g. a potted solid state relay). Ex m force the design of products that are encapsulated and or hermetically sealed and, by design, inaccessible for end user repair. Ex m is widely recognized in Europe.*

IMPACT: [NgII} *There are other methods of protection. Flameproofing (Ex d) requires bulky, unreliable filled conduit seals and/or glands to isolate wiring penetrations as well as special explosion-proof enclosures which in some cases may be quite large. Pressurization (Ex p) requires large continuous flows of clean "purge" gas as well as extensive purging hardware. (Pressure switches, regulators, tubing, etc.) Some purging requirements may require the use of an inert gas purge. (Some companies will not allow the use of an oxygen depleting inert purge as a method of protection.)* The Intrinsic Safety method eliminates the ongoing cost of purge gas and facilitates maintainability. [NgII] *Of especial importance, from a maintenance perspective is the freedom for our maintenance personnel to be able to remove and install components "live" without the need for hazardous gas "sniff" checks, no safe work permits or other procedures to ensure safe operation. Additionally maintenance can be done on a swap out basis. Considerable amount of maintenance on analyzer systems is done in-situ due to the difficulties associated with field removal.*

REQUIREMENT #3. Miniature, modular SP-76 compliant Temperature, Pressure, and Flow transducers are required in various ranges and configurations.

REASON: The ability to measure Temperature, Pressure, and Flow at any desired point in the sample handling system is necessary to validate the sample and provide primary inputs to final control elements such as heaters or flow control valves to condition samples as required by Process Analyzer manufacturers and *[NgII] End Users.*

IMPACT: It is anticipated that Honeywell S&C will supply sensors for both liquids and gases in accordance with the requirements of Table 3.

REQUIREMENT #4. Multivariable or "combi-sensors" (sensors capable of measuring P/T/F in combination) are preferred.

REASON: A goal of NeSSI is to shrink the size of sample handling systems, and the ability to obtain more than one measurand from a single 1.5" substrate location will help to reduce the overall system size. [NgII] *Having multiple measurands on board a device also simplify stocking of multiple types of devices by the End User.*

IMPACT: Packaging multiple sensors into one device increases the cost, complexity, and power consumption of the individual device, although it will reduce the overall cost and power consumption of the entire sample handling system. [NgII] *This power load could be mitigated by disabling (putting to sleep) those measurands which are not required for the particular application.*

REQUIREMENT #5. A single, standard, rugged, [NgII] *quick-disconnect* male connector shall supply all power and signal wires to each NeSSI transducer.

REASON: This makes it possible for [NgII] *maintenance* personnel to remove and replace NeSSI devices when needed. [NgII] *Of more importance is the desire to reduce the wiring bulk at the sensor/actuator level. Two connectors on top of the sensor would be crowding limited space and possibly lead to misconnection in some cases. Additionally since connectors are points of possible contact problems, it may be, from a reliability point of view, useful to limit the number of connectors which are in close contact to the sampling location. There is a strong need to have a small common, non-proprietary connector for device makers to adopt.*

IMPACT: The requirement for one connector per device eliminates some "daisy chain" wiring schemes and implies the use of some kind of "tee" or local wiring concentrator. [NgII] *We remain open to alternative suggestions.*

REQUIREMENT #6. [NgII] *Power* and communication signals to the NeSSI transducers must be capable of passing through a galvanically [NgII] *or optically* isolated intrinsic safety barrier.
[NgII] *Comment. All or must is too firm a statement. We realize that some devices, such as more conventional analyzers and sensors will not adapt well to a single IS barrier/ managed power system. At this point in time there are few miniature devices that are IS rated. We have suggested in the past that one of the two (or more) ports on the Sensor Actuator Manager (SAM) may be operated NIS. (i.e. no IS barrier) Consequently there is a high desire to ensure that any communication protocol we select is ambidextrous i.e. works with both a galvanic/optical IS barrier as well as for NIS. Power hungry devices such as heaters and certain analyzers may only require network signal communication but will require power (120 VAC or DC) sourced from an external source. (Our specification will be updated to add these points.)*

REASON: Use of an approved IS barrier(s) is required to comply with Intrinsic Safety (Ex ib) certification requirements. Circuitry on the IS barrier limits the energy that is available to devices in the hazardous area to levels that will preclude ignition.

IMPACT: Users prefer galvanically isolated barriers over zener barriers because zener barriers must be attached to a high integrity IS ground, which is costly to install and maintain. [NgII] *Zener barriers also consume precious power due to their resistive networks.* On the other hand, galvanic/optical isolation barriers must be designed for compatibility with the type of communications signals that are to be used. [NgII] *Many users in Europe are moving away from Zener barriers and going to isolation barriers.*

REQUIREMENT #7. Power consumption by each NeSSI device shall be minimized. (The Gen. II spec. suggests an allocation of 20-60 mw per transducer).

REASON: The Intrinsically Safe operating environment limits the total amount of available electrical power. It is envisioned that a typical NeSSI sample system may incorporate as many as 20 transducers that must share the total available current (approximately 280 ma at 15 VDC or 4.2 watts total), for an average of 14 ma max. per device or (210 mw).

IMPACT: Intrinsic Safety protection was designed for an architecture in which every device in the hazardous area is connected through a dedicated IS barrier that limits the available current and voltage. More than one device can be powered through a single IS barrier as long as the total available current is not exceeded, but even with low-current devices, this puts a premium on careful power budget management. While design tools may help, the NeSSI system designer will need to balance the power needs of each device vs. the number of devices required, always staying within the limits imposed by the IS safe operating region curve.

REQUIREMENT #8. NeSSI transducers shall be capable of "plug and play" identification.

REASON: To simplify initial configuration and subsequent replacement or addition of NeSSI transducers, it should be possible to automatically determine basic information about the device (such as manufacturer, part number, tagname, etc) by some electronic means. [NgII] *An industry wide addressing "standard" data sheet would be useful to provide a target for device suppliers. The standard "global" data sheet should cover the use of transducers in both wired (IS, NIS) as well as wireless interfaces.*

IMPACT: This implies the existence of some form of "transducer electronic data sheet" somewhere in the NeSSI system that will hold the information, and some means by which the sensor can electronically identify itself.

REQUIREMENT #9. NeSSI transducers shall provide inputs or outputs capable of being configured for various engineering units over various pressure, temperature, and flow ranges.

REASON: Table 3 of the Gen. II spec calls out all physical sensor (transducer) requirements, including full-scale output range, accuracy, and engineering units for each desired measurand. The intent of this requirement is clearly that users will interact with the NeSSI system directly in these engineering units (rather than having to deal with low level binary values, A/D counts, etc). [NgII] *Value added transducer features would be supplied as software with each device and be used to differentiate the product as the market and sophistication of the sensor design increases.*

IMPACT: This is basically a data presentation issue since the transfer function (null and full scale output) of NeSSI sensors will be fixed during factory calibration routines to the FSO values given in Table 3. Some communications protocols provide a mechanism for describing the desired engineering units which will facilitate meeting this requirement, and NeSSI suppliers should be required to comply with all requirements of the chosen protocol. It is also common for engineering unit conversion (i.e. PSI vs Kpa vs bars) to be done in higher-level controller or HMI. [NgII] *Transducers with on-board programmable ranges allow End Users to minimize inventory and provide a high degree of configuration flexibility for various applications.*

REQUIREMENT #10. NeSSI transducers shall have on-board diagnostics including heartbeat, self-testing routines, etc

REASON: This requirement facilitates the NeSSI Gen II goal of enabling Predictive Maintenance. [NgII] *Predictive maintenance reduces labour costs and increases reliability of analytical systems.*

IMPACT: The choice of how data is communicated from NeSSI transducers will have a major impact on the kind of internal sensor diagnostics and how they are implemented. Some diagnostics are related to internal functioning of the transducer whereas others typically must be inferred from conditions outside the sensor (i.e.loss of power or the ability to communicate).

REQUIREMENT #11. NeSSI transducers shall be capable of being software configured (for example) - liquid vs. gas selectable, engineering span rangeability, (e.g. ability to calibrate over a portion of a wider range), temperature compensation adjustments, specific gravity factor, etc.

REASON: This requirement reflects a desire to advance the state-of-the-art by making the sensors more capable, more flexible in application, more able to compensate for changes in field conditions, and to optimize performance.

IMPACT: Some of the examples given simply imply a change in how the output is displayed (engineering units), or a calculated output variable as a function of one or more measurand. However, it should be noted that the basic transfer function of most sensors is fixed during manufacture and cannot be changed in the field. [NgII] *Value added features could be supplied as software with each device and be used to differentiate the product as the market and sophistication of the sensor design increases. Transducers with on-board programmable capabilities allow End Users to minimize inventory and provide wide support and configuration flexibility.*

REQUIREMENT #12. Preferred NeSSI sensors shall have integral signal processing, A/D conversion, microcomputer, and communications circuitry.

REASON: The Gen II spec writers see this as a requirement in order to implement all of the previous requirements, i.e. it is a "how-to". [NgII] *Lower cost chips, lower power designs (driven by the need for battery powered, devices; "scavenging" power sources, energy conservation) along with state of the art technology suggest that this technology is at hand and may fit well with a ground up designed product. [It is important however, to note that the power draw required to make components smart (internal circuitry, transceivers) do not siphon off the lions share of the power allocation in any IS system.]*

IMPACT: While many engineers would agree with this assumption, this requirement must be evaluated against all other requirements, especially #1 and #4. Embedding intelligence into every device makes it more difficult to live within the IS power budget or to implement large systems with up to 20 devices. On the other hand, whereas combi-sensors where 2 more measurands share a single set of electronics tips the balance the other way. The amount and type of electronics embedded into each NeSSI transducer must be carefully considered in light of all stated objectives, cost, and value to the ultimate customer. [NgII] *Careful consideration to transducer power load vs. on-board features will need to be considered. The capabilities to provide transducers with on-board smarts is important but secondary to the ability to run multiple transducers on an IS network.*

[NgII] ***REQUIREMENT #13. Wiring to remove sensors and actuators shall be easy to disconnect and not require special mechanical protection.***

REASON: *Of very high importance is the ability to be able to wire up diagnostic and operational components (sensors and actuators at the manifold level) using simple connectors and "normal", non-protected wiring. Since wiring in many jurisdictions require mechanical methods of protection for hazardous areas, this adds extreme bulk to any wiring schema. This now is especially impractical in miniature, modular systems where a typical (smallest) flexible conduit size may be ½" in size. Furthermore the bend radius of these conduits, cables and associated flex connectors will increase the size of any enclosure. The worst case scenario would be that some of the manifolds would have to be broken apart to allow power/communication connection. 120 VAC power wiring conduit/cable can not be avoided, however since large devices like heaters require little if any maintenance and can not be run IS.*

IMPACT: *Without the ability to employ flexible wiring methods (e.g. eliminate hard or flexible conduits, large cables, sealing glands. filled conduit seals, etc.) for hazardous areas (both Div 1 and 2) the driver to move to smart, transducer based process analytical systems is not as compelling. Miniature components do not lend themselves to traditional hazardous area wiring methods. In some cases hazardous wiring interconnections may be larger in size than the actual components. We have proven this in systems employing miniature 4-20 mA sensors in NeSSI Gen I prototype installations. Today we have now gained a high degree of flexibility on the mechanical side of the equation using ANSI/ISA SP76 but we may lose it on the electrical side without a simplified wiring. (The USB standard comes to mind on how our network should look.) As one pundit stated: "Maybe we should have designed our systems around modular, X-proof electrical blocks and used tubing to connect the fluid passages."*

— NeSSI Gen II Specification Revision Log —

Revision History

Date	By	Description
Draft d6 May 26, 2003	D. Penney/R. Dubois; Peter. van Vuuren	Added PV2 revisions. Added Gen II prototype drawings. Significant revisions marked with a triangle. Figures redrawn. Added a Revision Log. Added the CPAC copyright.
Draft d7 April 29, 2004	R. Dubois	General revisions. (not released)
Working w0 June 14, 2004	R.Dubois/D. Penney; Jeff Gunnell	Amended SAM port requirements and updated Figs. 17a & b to align with DoE candidate dwg. revisions. Replaced CANbus/DeviceNet with "NeSSI-bus". Made IS Ex ib preferable over Ex ia to align with FISCO. Zone 0 made optional. All major section revisions marked with triangle, revised text hi-lited in blue. Added Appendix 1 and new Fig. 13. Fig. 10a and 10b combined into Fig. 10. General rewrite of Section 5 and 11 to eliminate redundancy. Minor revisions to Table 1. Added metric units in Tables 3 &4. General revisions based on comments received since release of draft version 6.