Technologies for Achieving Field-Ubiquitous Computing

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1. Future trend of Industries and Technologies

As the 21st century begins, globalization has become one of the key factors changing every aspect of the human society including world politics, economies and even our personal lifestyle. Manufacturing is not an exception. Our industries are enormously affected by globalization, in other words the borderless society.

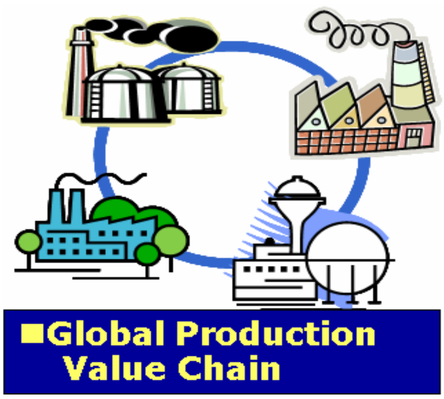
In the advanced countries, economic growth is almost saturated and a fast shift to the aging societies is becoming a big concern.

In contrast, in the developing countries, rapid economic growth is causing several problems including a lack of a skilled workforce, which threatens to block progress in quality and productivity improvement in the manufacturing industries.

Environmental protection and energy supply are growing global concerns as well. The negative legacy of industrialization through the 20^{th} century is beginning to threaten the very existence of our species. The entire world is becoming more aware of sustainability issues, as we begin to see for real that there is a limitation in both what we can take from and what we can force upon our natural environment. What we once thought limitless is no more. Global collaboration is essential to take on these challenges and the manufacturing industries must play a key role.

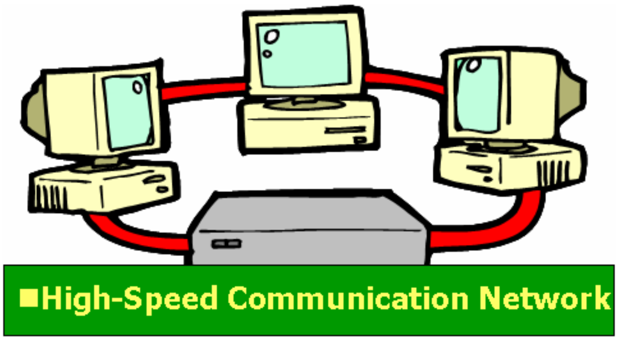
Ensuring safety and security is an old but relevant topic these days. The recent shift to an open environment in manufacturing systems requires maximum consideration for security protection as well as plant safeguarding.

The direct effect of globalization on the manufacturing industries can be seen in the recent progress of the global production value chain. Suppliers, manufacturers and customers collaborate in globally distributed value chains to create common value. Manufacturers today must embrace global networking as an essential part of their manufacturing processes.



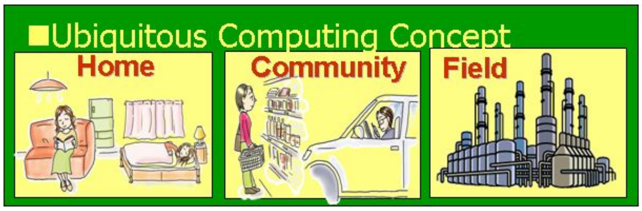
Also, if you look at the emerging technology trend, big changes are afoot in the manufacturing domain.

First, a high-speed communication network technology currently used in the enterprise domain is finally coming into the plant floor.



This will not only improve the speed of communications but also trigger a revolutionary change in operating processes.

The ubiquitous computing concept that has been well deployed in the home and office domains gives us foresight into the revolutionary change coming to the manufacturing domain. I will explain this topic later to analyze the implications of the ubiquitous computing concept.



The globalization trend is driving us toward world-wide collaboration, uniting local entities to create value that is global in scale. At the same time, it requires the manufacturing system to be agile and flexible, adapting to various changes quickly and meeting individual requirements more closely.

2. Challenging Tasks for the Future of Industrial Automation

Considering such changes in industries and technologies, I have distilled four key tasks that should be undertaken by the customers and the suppliers of industrial automation for the future.

1. More focus on the protection of health, safety and environment as the first priority
2. Enable flexible and agile adaptation to various changes in market demands
3. Meet personalization trend of products and production processes
4. Keep automation systems up to date for longer period

The first task is to protect health, safety and environment. This should be the first priority for all of us. Over the years, automation systems have come a long way to help customers reduce energy consumption and increase productivity in their plants.

In the coming years, automation systems will be more focused on the additional responsibility of protecting health, safety and environment, and ensuring sustainability of stable production.

The second task is to enable flexible and agile adaptation to various changes according to market demands. These days even in the mass production factories, the plant managers are required to produce various types and grades of the product with frequent changes in accordance with real-time order intakes from customers. Automation systems are required to have an enhanced capability to handle various types of production information more flexibly.

Another change found in the manufacturing industries is the emerging demand for tailor-made production, where a very small lot of a product is produced to meet an individual customer's order. In this case, the production systems and processes as well as automation systems must change constantly. I call this phenomenon the personalization of production. We should meet this trend as well.

Finally, keeping automation systems up to date for longer periods is an everlasting challenge. Even if customer demands are changing frequently, the plant and production systems continue to work for very long periods, such as 20 to 30 years. Automation systems should help to protect user-created assets such as control and production strategies over many years while system components are adequately updated using the latest technologies. Continuous efforts to develop new technologies and proactive adaptation to revolutionary changes in business practices are essential to take on these challenges.

I believe the ubiquitous computing concept is particularly relevant and promising in taking on the 2nd and 3rd challenges listed here. From here onward, I'd like to analyze the implications of the ubiquitous computing concept deployed on the plant floor.

3. Ubiquitous Computing on the Plant Floor

Ubiquitous computing promises to bring a lot of new benefits to our society -- in our homes, in our communities, and even in manufacturing plants.

The key benefits of ubiquitous computing can be summarized as enabling us to utilize information in the following ways.

- ✓ From anywhere
- ✓ At anytime autonomously
- ✓ Vividly as if on-site
- ✓ From user's viewpoint
- ✓ Quickly adapting to changes

<u>"From anywhere":</u>

Ubiquitous computing removes location dependency.

<u>"At anytime autonomously":</u>

Ubiquitous computing performs a variety of tasks autonomously at any time without requesting any conscious efforts on the users' part.

<u>"Vividly as if on-site":</u>

Ubiquitous computing does not block access to any information, and helps us to work remotely as if doing the task on-site.

<u>"From the user's viewpoint":</u>

Ubiquitous computing implements functions from the user's point of view, rather than from that of the system builders.

<u>"Quickly adapting to changes":</u>

Change is naturally absorbed in ubiquitous computing environments. Ubiquitous computing is capable of adapting to frequent changes in a flexible manner.

I am confident that ubiquitous computing is eagerly awaited on the plant floor and in the production field as well. For example, let us envision a plant where:

Sensors and control devices carry out continuous self-diagnosis and autonomously execute predictive maintenance to prevent malfunctions. A network enables you to operate your plant from any location around the globe and eliminates the necessity of stationing experts at each facility. Equipment and devices on the production lines engage in an autonomous dialog with human operators and are capable of adapting to unexpected changes by upgrading their functionalities online.

I named this concept Field Ubiquitous Innovation, ubiquitous computing applied to the plant floor.

Hereafter I will introduce some of our efforts to make Field Ubiquitous Innovation a reality.

4. Beyond the Traditional View of IT

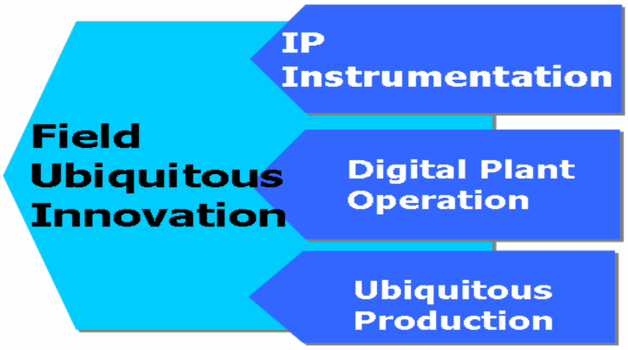
Traditionally we have believed the plant floor cannot allow a "reset culture" or "best practice based responsibility". Absolute responsibility, deterministic response time and deep real time are what we call the 3Rs that symbolize the essential characteristic of plant floor systems.

The recent BPR (Business Process Re-Engineering) experiences in office and enterprise domains give us foresight into the revolutionary change that will come to plant floor operations and management. It is a must to re-engineer the total operation flow in order to enjoy the full use of the latest IT.

I believe we can establish the remodeled 3Rs on widely used IT infrastructure

5. Technologies for Achieving Field Ubiquitous Innovation

I think there are a number of technologies required to make the field ubiquitous concept a reality. Today I'd like to pick up three of them which I believe are the most important, and give you some details about them.



The first one is IP instrumentation. Internet technologies, especially the IP network technology that has become a de-facto standard and has been widely used in the office and enterprise environment, will inevitably rush onto the plant floor like a tidal wave. We have sensed this tidal wave in development and have named it the IP instrumentation.

The base technologies supporting IP instrumentation include:

No.1: IPv6, a new version of the internet protocol, that will be applied to the field network.

No.2: Security technology that accommodates the requirements peculiar to the plant floor applications.

No.3: Wireless communications in the field environment that liberate customers from the restrictions of field wiring.

The second theme is Digital Plant Operation.

Taking full advantage of the rich information we can now gather on the plant floor thanks to distributed intelligence, we believe the methodology of plant operation will be fundamentally changed to a higher level, which we call Digital Plant Operation.

I will show you a few features of Digital Plant Operation using the following two examples:

No.1: A plant tracking simulator running on-line in real-time to uncover the hidden behaviors of a plant.

No.2: Abstracted plant operation that enables users more intuitive operation of the plant to achieve the final objective.

The third theme is ubiquitous production, which is a distinct element.

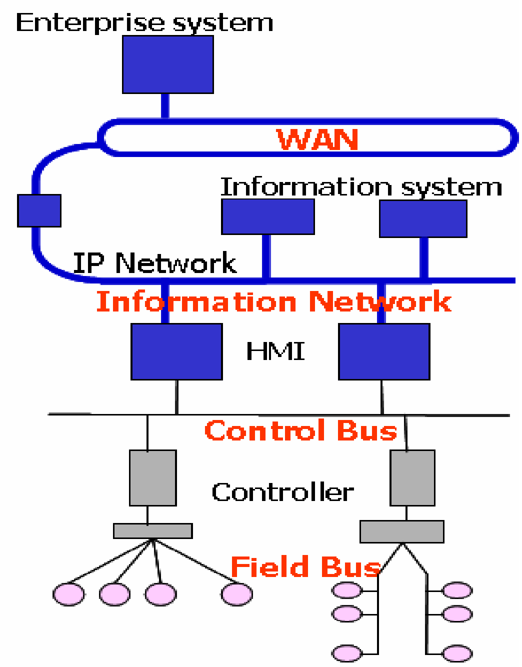
This is not built on IT based technologies, but leverages chemical based technologies. Micro reactor technology enables a new mechanism of chemical synthesis by bringing chemical reactions inside micro-fluid channels.

6. IP instrumentation

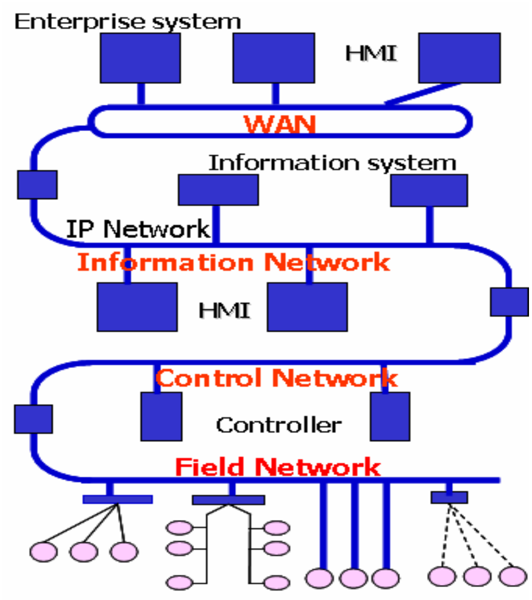
6.1. Architecture

The word IP instrumentation, namely Internet Protocol based Instrumentation, symbolizes the disruptive innovation when internet technologies penetrate the plant floor. Let me summarize the difference in architecture between the conventional system and IP instrumentation.

In the conventional system, different network technologies are applied to different layers. Enterprise level, information level, control level, and field wiring level, each has its own network. To utilize data, applications must be developed for each layer with exhaustive consideration of network characteristics.



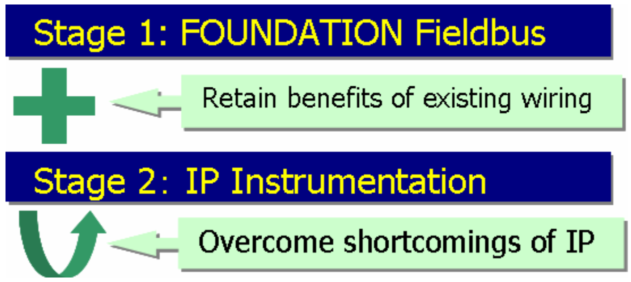
In contrast, in the expected system architecture of IP instrumentation, all layers will share an unifying network technology with IP. By unifying the system network, we can design more flexible systems that overcome traditional limitations such as the geographical barrier in remote applications. IP also improves connectivity between different systems, providing common network infrastructure for vertical integration and horizontal integration.



6.2. Road to IP Instrumentation

The standardization of FOUNDATION fieldbus represents the first stage of the disruptive innovation coming to the area of field wiring. It is replacing the conventional point-to-point 4-20mA analog communications with multiple-point digital bus communications. The data transmitted go beyond traditional process variables and incorporate maintenance data, configuration parameters, and so on. This change is enabling both wiring cost reduction and innovative utilization of extended field data. Further new benefits such as control in the production field, predictive maintenance, and asset optimization are on the way.

IP Instrumentation is the second stage of the innovation on the plant floor. We view Internet technology as one of the potential answers to emerging new requirements for more effective usage of extended field data, more flexible field wiring, and more adaptive production systems. This innovation promises further optimization of work processes that goes beyond control and monitoring, bringing increased capabilities and efficiency to maintenance and asset management and so on.



I think there are two key success factors for full-scale IP usage in the production field. The first key success factor is the retention of the user benefits that the existing field wiring has achieved so far. Concrete examples of existing user benefits include fast and deterministic real-time response and firm intrinsic safety capability. IP instrumentation must ensure the same level of reliability or dependability of field wiring that the users currently enjoy.

The second key success factor is overcoming the potential shortcomings associated with IP Instrumentation. I believe the following two issues are particularly important. First, the network must be secure and protected against cyber attacks.

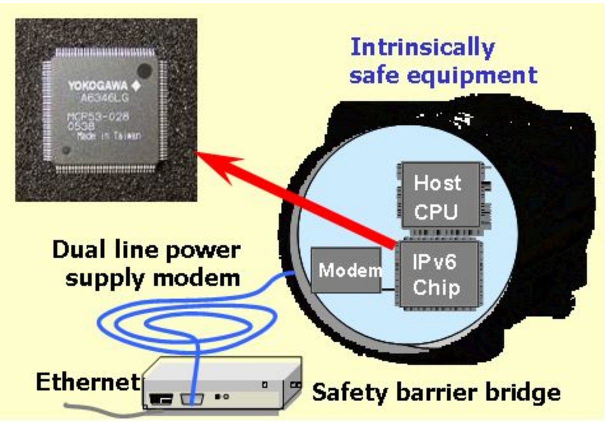
Secondly, the engineering environment must be well prepared for easy and cost effective integration work.

6.3. IPv6: next generation IP protocol

The Internet protocol is a network layer protocol widely used for packet-switched inter-networks. The current version IPv4 carrying a 32-bit length address field, supports about 4.3 billion internet addresses. This may sound like a huge number, but as internet communications become popular, a much larger address space is required to meet increasing demands.

Everything from personal items to huge government systems is going to require IP addresses for communications in the ubiquitous age. The new version protocol of IPv6 with 128-bit length address field supports a number of addresses that is equivalent to 10 to the 38th power.

IPv6 is not merely an address expander. IPv6 has the potential to offer more advanced encryption capability, much tighter security against network intrusion, and support of easy-to-configure connectivity to a wider variety of devices.



In order to dispel a common misunderstanding about the applicability of IPv6 in a very harsh production field environment, we have developed an IPv6 chip specifically designed for field devices. This innovative IPv6 chip has a TCP/UDP protocol stack and built-in security functions in the hardware layer, thereby enabling field devices with limited CPU resources to utilize IPv6. In the link layer, it allows two-wired modem connections in addition to Ethernet connections, thereby enabling 1km long-distance transmission, power supply, and intrinsic safety.

We believe FOUNDATION fieldbus will continue to play a key role in IA systems. We are now developing software architecture to enable Foundation Fieldbus applications running on IPv6.

6.4. Field oriented network security

The embedded security function provided by IPv6 is a base for achieving a secure field network. But we have to promote further enhancements to ensure secure communications on the plant floor. The conventional firewall model of network security is getting out of date as mobile terminals and wireless connections come into play and collaborative manufacturing among geographically remote facilities becomes a reality.

In the emerging new environment, it is critical to establish a secure communication channel between both ends, not assuming any specific network topology. As an answer to this challenge, we are developing what we call a secure plug & play mechanism. This is a security framework applicable to low-end as well as high-end field devices, enabling easy plug & play engineering and network security simultaneously.

Furthermore, protecting individual field devices is not sufficient as a comprehensive network security measure. The network itself must be safeguarded against communication errors and network malfunctions which would could arise from cyber attacks.

Our challenge will continue.

6.5. Field wireless communications

The third key technology that enables IP Instrumentation is wireless technology. People in the industry community used to be rather skeptical about introducing wireless communications in the manufacturing field because of its physical limitations and security vulnerabilities. Now they are becoming more positive about its potential benefits.

Expectations for wireless solutions include freedom from the restrictions of wired connections of field devices. This change of attitude is remarkable especially in oil & gas upstream and other industries that operate widely distributed facilities in areas where communications infrastructure is minimal. Also for maintenance purposes, people want to install additional sensors, without having to give careful consideration to the network configuration beforehand. This is one of the potential applications for wireless solutions.

Still I understand wireless solutions are facing several obstacles in the field.

Wireless solutions always suffer from a limited power supply. Sometimes devices are installed without any power supply, and are expected to have their own power source. Power management is a mandatory feature for field wireless devices. Typical plant floors and production fields are full of metal tanks, pipes and noise-generating machinery that interfere with wireless communications, by reflecting, absorbing and interfering with radio waves.

Grappling with such issues requires a quite different technology from the wireless in the office domain. And security protection is another important task in wireless solutions. We are accelerating our R&D activities in three key areas.

The first area is the development of key elemental technologies for the field wireless network. Our research is focused on the mesh network system as well as the gateway system that bridges IP and wireless networks.

The second area is prototyping of wireless units and evaluation of their applications.

The third area is activities for international standardization. Interoperability of field devices is essential and international standardization of the field wireless protocol is an issue that must addressed. We are actively participating in both the ZigBee alliance based on IEEE802.15.4 and the ISA SP100 standardization activities.

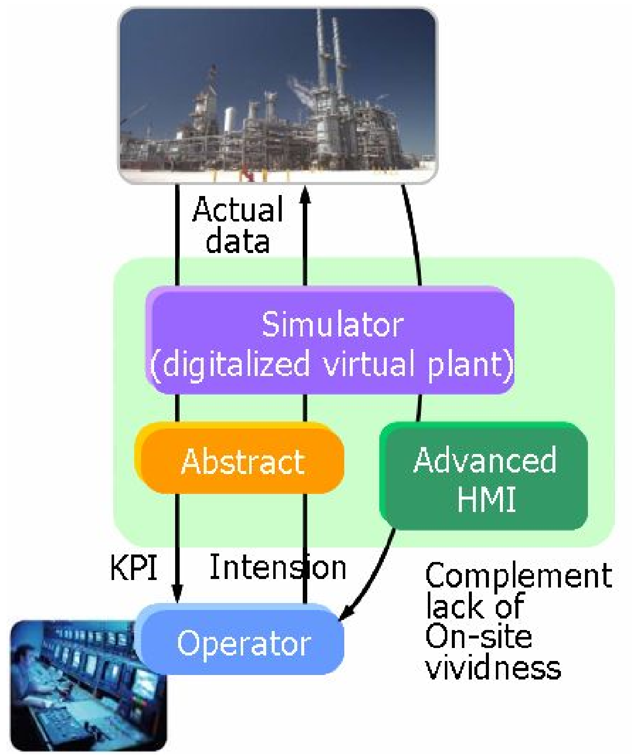
Besides these key activities, we are starting to work on the vision of dependable wireless communications. Wireless means no physical wire that can be cut off. It has a potential to evolve into an extremely reliable network. I firmly believe dependable wireless communications will grow into an essential complementary component of IP instrumentation.

7. Digital Plant Operation

The next topic is about digital plant operation, which is the second research theme to help realize the field ubiquitous innovation. We are aiming to achieve two targets with digital plant operation.

The first target is to realize a transparent operation. Transparency means you can see the inner behavior of the plant according to your particular purpose. Also you can see the fundamental behavior of the plant before the distortion caused by individual implementation constraints such as the different configurations for plant equipment at each plant.

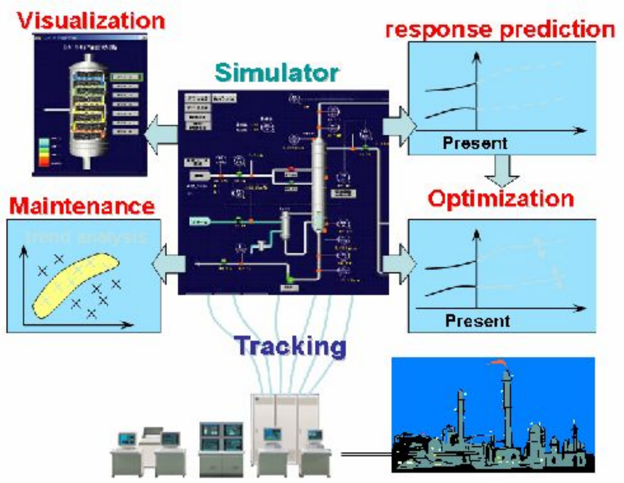
The second feature is realizing an abstracted plant operation. First make operators understand the plant more intuitively using the KPIs (Key Performance Indicators) that essentially describe the plant. Then, the operators manipulate the plant with a primary intention such as “produce how much volume of the product with what quality level”, instead of conventional physical actions such as “manipulate of the valve opening 3%”.



The upper figure shows a typical scheme of a digital plant operation. The plant simulator is placed in the center of the scheme producing the predicted plant inner behavior and calculating KPIs. The advanced HMI is another key element that complements the lack of on-site vividness that may be caused by such an extensive use of IT. The advanced HMI is beyond the scope of this paper.

7.1. Plant Tracking Simulator

The plant simulator used in such a scheme is a dynamic simulator running on-line in the real plant operation. It collects actual data of the real plant through the DCS and runs simulation iteratively to adjust parameters of the plant model in order to make the model equalized with the real plant. This is what we call the tracking simulator.



The tracking simulator visualizes the inner status of the plant by interpolating and estimating unmeasured process variables. It also supports plant monitoring and maintenance with calculated KPIs. More importantly, it enables the prediction of the future dynamic behavior of the plant by accelerating calculation in the simulator. Using case simulations with varying parameters, it can help determine the optimal conditions of plant operation in advance.

7.2. Real-time utilization of plant models

This slide shows how the tracking simulator uses the plant model on-line and in real-time. The tracking simulator simultaneously runs with the real plant, and continuously adjusts model parameters by comparing the response of the real plant to the model using a tracking algorithm. Over time the simulator gets to behave in almost exactly the same way as the real plant.

The adjusted parameters are transferred to the prediction simulator or to the static simulator by the user's commands. The prediction simulator runs accelerated simulation in order to predict the future behavior of the plant. The static simulator is used to predict the steady state of the future.

8. Ubiquitous Production with Micro Plants

Micro reactor technology enables a new chemical synthesis by bringing chemical reactions inside micro-fluid channels, enabling a safe and environmentally friendly small-quantity production method. Micro reactor technology is expected to lead to a significant innovation in the chemical industry's manufacturing process. Micro-reactors reduce reaction time and enable highly selective production of intermediate compounds.

In addition, when moving to mass production, micro-reactors can simply be multiplied in number, avoiding all the problems generally associated with the scale up process.

The leading technologies utilized for micro reactors are the MEMS technology and the micro flow technology.

8.1. On-site F2 Generator

One concrete example of a micro plant prototype is an on-site gas generator using an electro-chemical micro reactor. Today, fluorine gas is made in large chemical plants and packed in high pressure gas cylinders, which are then transported to semiconductor factories and connected to the gas supply piping of semiconductor production equipment. Using an On-Site Fluorine Gas Generator, customers can reduce cost and improve safety.

Under such a production system, exactly the necessary amount of products can be produced anytime at the very site of usage. This is “ubiquitous production”.

9. Closing

To end my paper, I would like to reconfirm a few key points of the field ubiquitous innovation.

(1) We have introduced various new technologies into automation systems so far but we have been still bounded and trapped by the very traditional IA culture. As the 21st century begins, it is one of the inevitabilities of history that we start to enjoy the real benefits of information technologies, such as internet, world-wide-web browser and so on. To do so, we must loosen up the rigidity of the traditional plant instrumentation, breaking it up into a lot of right pieces and rearranging them on the internet world.

(2) IP instrumentation is indeed the very key platform for this revolution but it is still just a prerequisite for a much broader change required. It is very important to adapt the business models and operational philosophy to the new platform in order to bring out the effectiveness of IP instrumentation. The digital plant operation concept is the key vision that ushers in this broader change.

(3) The physical plants themselves are not an exception from the emergent change. The physical plants themselves will start adapting to the new age opened by IP instrumentation. Ubiquitous production by the micro plant technology is one illustration of the new forms of physical plants to come in the digital plant operation era.

I believe that IP instrumentation will realize collaborative production over the Internet world and bring operational efficiency to the next level. It is my dream to enable such new styles of operations as centralized plant operation from the skyscrapers and outsourcing of asset management services.

(END)