Rational Instrument Management
Learning From Observation and Identifying Best Practices

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The number of instruments and devices on the periphery of processing systems can easily number in the thousands. As a result, it is important to implement a naming convention for these instruments and devices that follows a logical sequence for ease of system management and development. In process-driven industries, instruments such as controllers, valves, sensors, and switches are often identified by an alphanumeric designation or TAG that provides information to a wide range of users. Managing how this information is generated and maintained can translate into a wealth of paybacks across the enterprise over the life of any given system.

This article examines how identification standards can quickly yield detailed, easy-to-understand, and reliable representation of instruments and devices. Rational instrument management (RIM) offers a well-structured systems approach to managing process and instrumentation devices. Many users can benefit from such an approach because it provides clear sightlines into the often-tangled web of process lines, including the following:

- Process design engineers
- Project managers
- Quality assurance and compliance professionals
- Plant calibration and maintenance personnel
- Automation engineers
- Manufacturing execution system (MES) implementation experts
- System integrators.

THE NEED IN BATCH-MANUFACTURING INDUSTRIES
Pharmaceutical and other batch-manufacturing processes typically evolve into complex systems. Users of these systems include not only engineers with process and instrumentation know-how but also other less technical personnel who need to see what is going on quickly. Long gone are the days when system drawings—with handwritten mark-ups by the people who really understood the system—were taped to the inside of the control cabinet door. Today, automation, networks, and the enterprise-wide sharing of data drive the need to manage process and instrumentation devices.

Other forces, ranging from intra-organizational dynamics to globalization, play a role in how processing systems are designed and managed. Technical innovations, such as the merging of engineering and production data made more readily possible with computer-aided drafting (CAD) applications, have also made a significant contribution. CAD ushered in the use of hyperlinks (also called tags in object-oriented programming) to represent information embedded in data tables. With the evolution from paper to supervisory control and data acquisition (SCADA) (1) to distributed control system (DCS) (2) to enterprise-wide networks, that information has become available to all users. If tags are structured correctly at the design stage, system programmers can pull information from a single source, hence reducing potential duplication and the incidence of missing data.
Systems can now be purchased from all over the world, which can make compliance to any one standard quite challenging. The English name for a pump (manufactured in Singapore) might not be the same for a German manufacturer who purchased it in Japan. Another challenge is that the players involved in design and commissioning may be different from those involved in system validation and qualification. Capturing the right data in the initial phases of the project can yield multiple returns in the latter phases of the system’s life cycle.

Hence, there is a real need to standardize instrument tagging and manage the various system components from the ground up. Instrument tagging must not be a patchwork of complicated code numbers, but rather a simple and effective means of identifying system components. Ideally, what are needed are tools that provide a roadmap for organizing an automated facility. Such a well-planned system delivers benefits to all stakeholders.

**Case Scenario 1**

It is just past 11:30 on a Sunday evening: the third shift is set to start soon. Your human machine interface (HMI) shows green (open) on your primary pump loop; however, when you look at the field device (FCV-122-001), you see the valve is clearly closed. The flow indicator on the HMI is identified as FI-122-01. The valve on the process and instrumentation diagram (P&ID) reads FCV-122, and it would clearly have to be open for flow to occur. With 100,000 liters of product about to be compromised, the inconsistency in tagging has become a real problem.

**AN EMERGING SOLUTION**

RIM has emerged as a systems approach to managing process and instrumentation devices. In the design phase, RIM makes use of good engineering practices (GEP); in the implementation phase, it fans out to all areas where instrument identification plays an important role. As design requirements are drafted, tag numbers are assigned. From that point onward, the impact of instrument tagging reverberates throughout the enterprise from process design to the use and maintenance of the system long after the P&IDs have been filed away.

RIM is easily implemented for new facilities. It can also be implemented for upgrades to existing facilities, including upgrades due to expansion, process or product improvement, and remediation in compliance with regulatory and quality requirements. The RIM-SDLC (systems development life cycle) illustrated in Figure 1 provides a conceptual overview of the entire process.

**UNDERSTANDING YOUR CLIENTS AND THEIR SYSTEM**

RIM requires a good understanding of both client needs and their system requirements as well as careful examination of every phase of a system’s life cycle. This is especially true given the number and range of personnel involved throughout system design (3), development, and implementation. A short list of system customers can include: sales and marketing, operations, purchasing, manufacturing, shipping and receiving, production and inventory control, engineering, IT, quality management, and suppliers—which suggests the magnitude of the challenge involved in process and instrument management. Most of these stakeholders will never see a P&ID, but their interests are inex-
trically tied to the language of process design and engineering.

Is there a way of linking these divergent concerns across the divide of process design with cryptic symbology of the P&ID? The answer is yes.

**A BASIS FOR INSTRUMENT TAGGING**

A standard issued by the Instrumentation, Systems, and Automation Society (ISA) provides the basis for many tag-numbering schemes (4). ISA is the main source for this specification and many other resources that can be used when designing systems, training, and developing standards for instrumentation. ISA 5.1 prescribes a systems approach to building a tag numbering system. ISA 5.1 defines the use of functional descriptors (e.g., FIC = flow indicating controller) followed by a series of user-defined numbers (e.g., loop 100) for the basic tag FIC-100. Optional prefixes and suffixes can then be added to build a specific number that allows the system designer to provide the necessary amount of identification information (e.g., B05- FIC-100-001 for building 5, flow indicator controller no. 1 on loop 100). Figure 2 shows a sample of identification letter building blocks for flow, temperature, and pressure.

**Letter Combinations**

Typical letter combinations, defined in ISA 5.1, form a functional description of what an instrument is and how it works. As shown in Figure 2, the first letter is expanded up to four places to form a complete mnemonic that can be used to define almost all instruments. PIC, which stands for “pressure, indicating, controlling,” would read TIC and FIC for temperature and flow, respectively.

Currently, there are approximately 220 combinations in ISA 5.1, R1992, Table 2. The letters A to Z are used to represent functional descriptors. Loop identification is achieved through use of the first letter, followed by a series of numbers (e.g., “T” and “100” for TIC-100). The loop can be serial or parallel: designated by TIC-100, TIC-101, TIC-102, and so on for serial and TIC-100 and PSH-100, for example, for parallel. System size and future expansion should be considered when adapting the standard for specific use (e.g., TIC-100-01 limited to TIC-100-99 vs. TIC-100-001 to TIC-100-999).

**Instrument Form Designation and Line Symbols**

Instrument form designation and line symbols are identified in ISA 5.1. Figure 3 illustrates how alphabetical, graphical, and numeric combinations form mnemonics that are used to provide a complete description, typically found on the P&ID.

ISA 5.1 describes how process systems are represented in a P&ID, schematically through the tag number, shape of symbols on the schematic, and type of lines connecting the symbols. Electrical signals are represented by a dotted line. The tank, valves, and a pump are also shown in Figure 3. Even the location of the instrument shown in the bubble with PIC 10-100-001 is determined by the double line bisecting the circle. This means that this instrument is discrete and in an auxiliary location, perhaps mounted behind an electrical enclosure near the M (electro-mechanical) actuator for the valve.

The arrangement of these symbols also has meaning and generally follows a logical sequence. The pressure element PE-10-100 detects a value that PT converts to an electrical signal, which the PIC-10-100-001 controller uses to modulate valve PV-10-100, allowing

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**Figure 2:** ID letter building blocks. This is a partial list (see ISA 5.1, Table 1 for complete reference [1]).

<table>
<thead>
<tr>
<th>First-letter (4)</th>
<th>Succeeding-letters (3)</th>
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<tbody>
<tr>
<td>Measured or initiating variable</td>
<td>Modifier</td>
</tr>
<tr>
<td>F</td>
<td>Flow rate</td>
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<tr>
<td>T</td>
<td>Temperature</td>
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<td>P</td>
<td>Pressure</td>
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level control of the tank to be maintained. At times, these signals are modified to represent how the signal is passed through by a multiplier or a non-linear (exponential or logarithmic) function as is often established by the functionality of the instrument.

The solid lines represent primary process material lines (e.g., water). There are alternate connection lines for pneumatic, hydraulic, and other lines that can be represented in a process. Even with an elaborate drawing scheme, the information in these call-outs does not provide enough detail. A complex tag-numbering system shown in Figure 4 expands on the design requirements, adding more functional and location information.

Even with all this information, the complex tag number does not tell the complete story. With any more detail, the designer would have a very crowded drawing. If there were much less detail (e.g., PIC-01), the representation becomes meaningless.

All of this raises the question: how much information is too much and how much is too little?

Case Scenario 2
A pharmaceutical company used three different design firms in the startup and implementation of its greenfield manufacturing facility. The design firms all used different systems based in different countries, following a variety of standards for TAG identification. There were thousands of components from all over the world with specifications written in several languages. The firms had their own idea of how instruments should be identified. Duplicate tag numbers showed up when the instruments came due for scheduled maintenance. There wasn’t enough time to get everyone on the same page.

Figure 3: P&ID form designation and line symbols (5).
page at the start of the project. The problem resurfaced at the end when the pharmaceutical company had to re-execute the commissioning and validation steps multiple times, incurring costly delays.

ACHIEVING INFORMATION BALANCE WITH AN INSTRUMENTATION DATABASE

Consider the power and flexibility of an instrumentation database (see Figure 5), which allows the system designer to start with the basic flow diagram and can be expanded as the design unfolds. Traditional systems allow the various factions involved in design to pull numbers and allocate designations as they build the system in the SDLC sequence. That is, user requirements and functional specifications are established up-front—and design, implementation, verification, and maintenance follow.

This model starts with the design and requirements definition steps in tandem through assignment of functional definitions at the front end of the process in the process flow diagram. The database assigns the next sequence number available, while facilities engineers populate building spaces. This can be followed by: MES and purchasing, calibration, maintenance, and so on in a more collaborative fashion—and all the stakeholders can reach the finish line once the designs are qualified. The quality and validation systems provide the checks and balances needed to ensure that due diligence is followed from the original requirements through to system release for use.

The database model in Figure 5 illustrates the flow from process design where only the fields needed to define the process are included. Construction of this model begins with the simple process flow diagram that grows into the tag number and is linked to the center hub, the instrument index. The device specifications are appended as the process design evolves, and that information is linked to the purchasing system. Figure 5 shows the facility engineering elements necessary in the initial phase of the project. Calibration and preventive maintenance tables are then added in these initial stages. Not shown are the infinite other functions that come into product realization, MES that are used to measure and control critical production activities. MES provides the metrics for traceability, productivity, quality, system commissioning and validation, document and equipment change control, product design history, labor tracking, inventory management, enterprise resource and planning systems (ERP), and vital financial data. The database also provides the key elements used in any modern facilities automation system (i.e., distributive control [DCS] and SCADA).

It is important to note that this model is the front end of a continuum where whole blocks of the information systems used in modern businesses are added later. By building the database model at the front end of the life cycle design, the enterprise can grow in logical sequential phases. In this way, relevant data can be captured at the front end of the project by structuring the system around the process first. Almost all of the systems talked about here are structured around a database engine running behind the applications. Building the structure around a database initially makes sense.
The following are other advantages to this approach:

- Field structure in the database can ensure consistency (e.g., use a numerical value not text)
- Exercise control in how the data are managed
- Use the flexibility of the database to customize queries and reports
- Share the data with the entire organization
- Prevent incidence of duplicate or omitted data
- Grow the system by adding modules when they’re needed
- Leverage database applications already ubiquitous in your organization.

AN OPPORTUNITY TO BRING THE EXISTING SYSTEM UP TO SPEED

Why not borrow the horsepower that Six Sigma brings to bear on projects and pull systems data into a shared database that allows the measure and analyze aspects of the DMAIC (define, measure, analyze, improve, control) process to be harnessed? The cross-functional breadth and size would require a Six Sigma level commitment to convert an existing plant automation system over to a shared platform. The cross-functional structure of Six Sigma (Green Belts, Black Belts, Master Black Belts, and Champions) is very effective in identifying problems, and then putting teams together to solve them.
HOW TO MAKE IT HAPPEN
The extent of the function and loop identification defined in ISA 5.1 is limited to just the basic process requirements typically found in any industrial or laboratory process application. The designer/owner can then apply more specific identification by adding unique designation for serial number, building number, plant area, room number, etc. The standards for your process engineering department will undoubtedly be somewhat customized to fit your application but this should only be done to the degree that additional information is needed. The rule of thumb is to add only data that you can afford to maintain and that will be used. If you think you may need to squirrel away some data that you can easily collect now—and you are unsure if the data will be needed later—collect them in a separate file or link them as a data-access page so they can be managed off line. It is better to have no records than out-of-date or flawed data. If you later decide to pull these data into your system, remember that to migrate an electronic record used in a regulated environment may require 21 CFR Part 11 assessment (6).

Structuring a tag-numbering system resembles most other project management efforts. The process of defining the system starts with the end goal in mind then flows backwards to discrete tasks that are fleshed out along the way. Rational instrument management requires that an integrated approach to system development be used during development.

There are a variety of business system level networks that can be used to drive information-sharing that require input as the system is built (e.g., the process design engineer sizes the flow indicator while the facilities engineer requires an output alarm for low water-tank level on the same loop). Boundaries are established and controlled by the SOP and the decisions are moved from queue to queue via the network.

The cost of maintaining the system is weighed against the value of having control. The value of having to update a data field on 6000 records should be weighed before those fields are added to the system database. Change control is a key component in the development of the system but its role as a facilitator must be clarified up front.

The top-level deliverable is the goal, and each successive level is driven by the completion of detailed input as the project progresses toward its conclusion. This process is similar to an indented structure used in planning. RIM requires input in the development process horizontally as the project progresses.

GETTING BUY-IN
As with any multi-disciplinary effort, the key to success is to isolate the responsibility of the person in charge and provide the authority necessary to get timely input from the assigned team members. Different departments have to be brought on board to make this effective (i.e., purchasing says to a supplier: “Can you follow our numbering system or can we cross-reference a unique part or serial number of yours?”).

CONCLUSION
When it seems that the batch-manufacturing industry has moved horizontally away from specialization, RIM can help those who are a drowning in a sea of information. Its main ingredients are timing, organization, knowledge, and, most important, people. Technologies already exist for sharing information, but as the horizontal component grows wider, staying abreast of what is going on in the “next cubicle over” requires a commitment to communication because that cubicle may be on the other side of the globe.

The following recap the main points presented in this article:
• Build your processing system around globally accepted standards
• Keep the design simple and at a high level at first; customization can occur in the next phase
• Use a database to ensure consistency and share information
• Institute a means of controlling growth at the development stage instead of at the pre-production phase
• Understand that the system designed today will look significantly different tomorrow. Flexibility and a means to track changes are critical in a regulated world.

REFERENCES
ISA References
4. Instrumentation, Systems, and Automation Society (ISA). Founded in 1943 and based in Research Triangle Park,
North Carolina, ISA is a leading, global, not-for-profit organization that is a world-class source of standards for automation and of solutions for its members and other professionals faced with challenging technical problems. ISA develops standards, certifies industry professionals, provides education and training, and publishes books, technical articles, and multimedia products. It also hosts conferences and exhibitions for automation professionals. Visit ISA online at www.isa.org.


Also see:
- ISA 5.3-1983 Graphic Symbols for Distributed Control/Shared Display. Instrumentation, Logic and Computer Systems.
- ISA 5.4-1991 Instrument Loop Diagrams.

**Relevant Standards**

ISO and DIN standards of relevance to rational instrument management discussed in this article are:


DIN 19227: “Graphical Symbols and Identifying Letters for Process Control Engineering (Germany).”

**General References**


**ARTICLE ACRONYM LISTING**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>CAD</td>
<td>Computer-Aided Drafting</td>
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<tr>
<td>DCS</td>
<td>Distributed Control System</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource and Planning Systems</td>
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<td>FIC</td>
<td>Flow, Indicating, Controlling</td>
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<td>GEP</td>
<td>Good Engineering Practices</td>
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<td>HMI</td>
<td>Human Machine Interface</td>
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<td>ISA</td>
<td>Instrumentation, Systems, and Automation Society</td>
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<td>MES</td>
<td>Manufacturing Execution System</td>
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<td>Process and Instrumentation Diagram</td>
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<td>PIC</td>
<td>Pressure, Indicating, Controlling</td>
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