



Understanding Loop Diagrams & Process Loop Sheets

Detailed drawings conforming to the ANSI/ISA-5.1-2022, Instrumentation Symbols and Identification, standard show how all devices and equipment are wired to the control system.

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From an installation and maintenance electrician's point of view, two of the most useful types of drawings that can be included in a contract drawing set are loop diagrams and process loop sheets. These detail drawings show how each piece of equipment (e.g., instrument, motor starter, valve actuator, etc.) is to be wired to the control system. This article provides an overview of loop

diagrams/process loop sheets and explains why creating and maintaining them is worth the effort.

From P&IDs to process loop sheets and diagrams

Piping and instrument diagrams (P&IDs) are developed at the beginning of a project to define the equipment, piping, and automation

and control components needed to implement a process, including the control loops. P&ID drawings provide an overall summary of the process. Together with facility layout drawings, the P&ID drawings provide an overall view of a facility, what it does, and where the equipment is located. For large facilities, an additional set of drawings called process flow diagrams (PFDs) are sometimes created to summarize the P&IDs even further.

With the P&ID drawings in hand, the various design disciplines can create individual drawing sets to show how different aspects of the plant are to be built. These will include structural drawings, civil engineering drawings, architectural drawings, mechanical drawings, electrical drawings, and so on. From an electrical and instrumentation/control perspective, these drawing sets will also include electrical power distribution (lighting panels, MCCs) drawings, control panel drawings (e.g., PLC panels), and loop diagrams and/or process loop sheets.

The instrumentation/control designer determines whether to use loop diagrams or process loop sheets. They both provide similar guidance for installation and maintenance electricians but, depending on the project type, one may be a better fit than the other.

A process loop sheet (PLS) provides the details for loops by illustrating all the devices and equipment in an instrumentation loop, how the various pieces interact, and how the process data is transmitted to the control room. It only provides summary information about the individual wiring details. Alternatively, this information can be arranged in a loop diagram

(LD) format, where the same information is shown but in the form of more detailed wiring instructions on a wire-by-wire basis down to the terminal screw.

Loop diagrams and process flow sheets make it possible for many design issues to be seen and rectified during the design phase rather than during construction.

Depending on the contractor or maintenance team, either process loop sheets or loop diagrams may be more suitable. The chief takeaway is that it is better to work out the wiring details of instrumentation and control devices during design rather than during construction. It is much easier (and cheaper) to make design decisions than to have an electrician trying to sort out the design while the construction clock is ticking.

A water and wastewater example

For example, water and wastewater plants are typically designed to accommodate influent flow rates that are not consistent from one hour to the next. These flow rates are generally expressed as low flow rate, average daily flow rate, and maximum flow rate, and are indicated in the description blocks on the process loop sheet. In a typical water/wastewater plant, there are generally pump stations, screenings and grit removal, clarifier

filters, odor control, various types of chemical injections, and storage tanks in the process loop, all of which may affect the flow rate. Flow, pressure, and temperature measuring devices transmit

data to local PLC/DCS control panels that interface through software with operator workstations typically located in the central control

room. The loop diagram shows the processes and equipment in the control loop, and the process loop sheet provides explanations and other essential information. Sometimes the loop diagram and process loop sheet are combined as a single drawing.

Throughout the life of the instrumentation system, including its construction, installation, commissioning, and operations, process loop sheets are accessed by personnel in multiple disciplines in the enterprise, as well as vendors and contractors. It is a resource used to document and explain how the control system and its instrumentation, motor starters, and valve actuators have been designed to operate and how they have been installed.

Due to the number of people using loop diagrams and process loop sheets, it is recommended to use a standardized symbol and nomenclature structure so everyone involved in the project can understand the components and the process. The best practice is to use the symbols and terminology developed

by the International Society of Automation (ISA) and documented in ANSI/ISA-5.1-2022, Instrumentation Symbols and Identification. It is equally important to ensure that the

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information on the process loop sheets is complete. Also, as with any drawings, the sheet should be assigned a revision date and include the name of the designer who last updated and checked it.

Loop diagrams explained

Put succinctly, a loop diagram is a type of detail drawing that shows—on an instrument-by-instrument and device-by-device basis—how input/output (I/O) signals from equipment are to be wired to the control system. Loop diagrams show the specific wiring details down to the level of terminal screws, junction boxes, cable labels, and wire labels.

Most loop drawings (see Figure 1) are produced using a computer-aided design (CAD) package or auto-generated by an advanced plant design software package. A loop diagram is usually focused on a specific instrument or device but may include multiple sensors/actuators if they are related to each other process-wise. The use of “typicals”

(a generic diagram that applies to multiple instruments/devices) is not recommended, as it defeats the purpose of the loop diagram containing instrument/device-specific I/O addresses and wiring details. Loop diagrams are generally the same size as other drawings in the drawing package for the plant. For example, the use of B-size (11" × 17"), D-size (22" × 34"), or E-size (34" × 44") drawings sizes are relatively common in North America.

Loop diagrams are not a new concept. ISA standard ISA-5.4-1991, Instrument Loop Diagrams, covers a general version focused on instrumentation I/O wiring. Commonly known as ISA-5.4, the ISA loop diagram standard has been around since the 1950s

and includes many good examples and best practices for creating effective loop diagrams.

Process loop sheets versus loop diagrams.

Process loop sheets, developed later, are a type of summarized loop diagram that includes additional process information. They are intended to help the installation and maintenance electricians install and troubleshoot equipment and provide additional context regarding its use. This context typically includes minimum and maximum temperatures, pressures, flows, and other process values, along with expected signal values during start-up, shutdown, steady-state and at-rest conditions. For example, a process

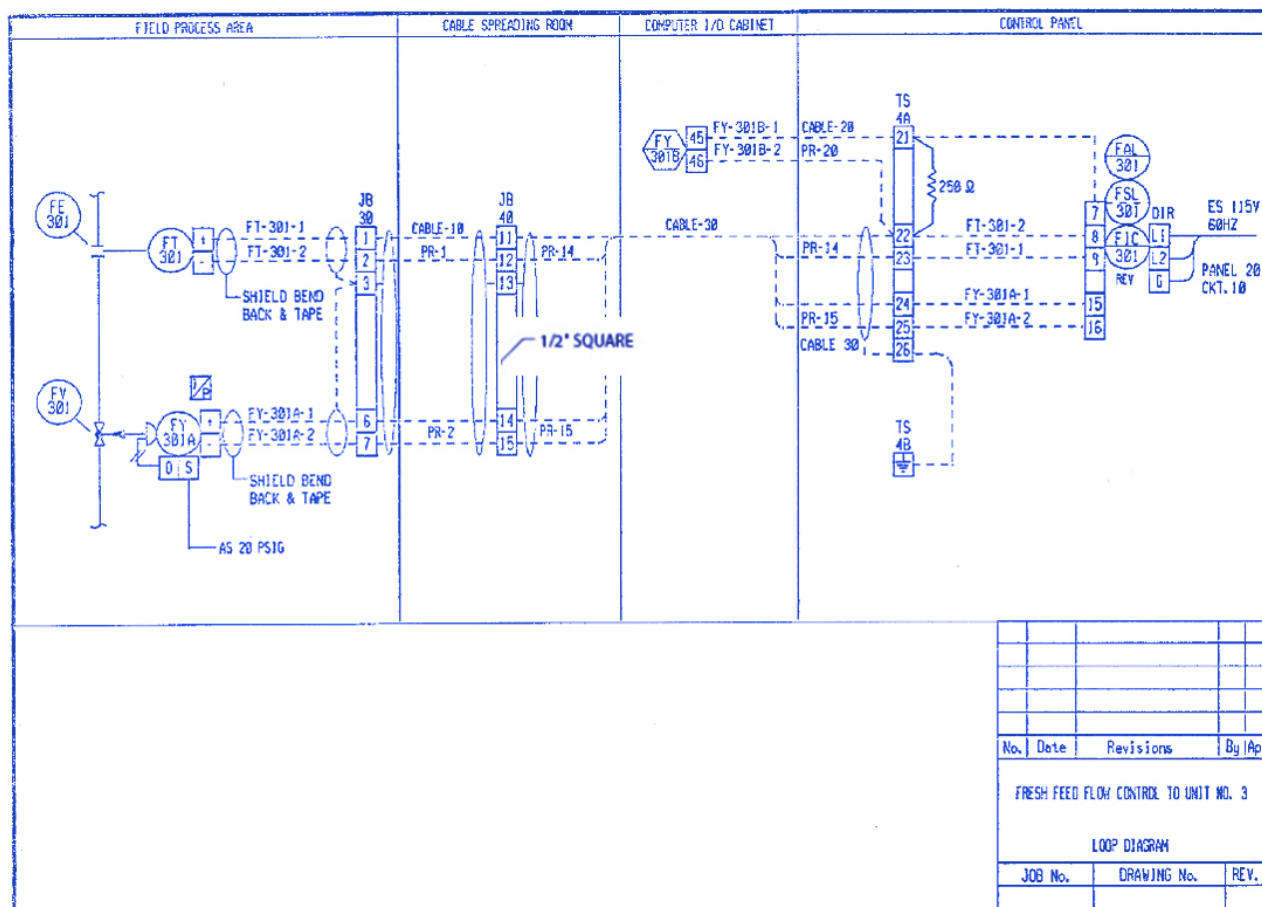


Figure 1. Example of a loop diagram. Source: ISA-5.4-1991. Reproduced with permission.

loop sheet for a magnetic flowmeter is shown in Figure 2. In the sample loop sheet, a flowmeter is reading the flow through a bar screen, totalizing it and then sending the reading to a PLC remote I/O panel. The reading is then used for various functions within the automation system.

Using loop diagrams and process loop sheets has been

standard practice for many years in various industries, including oil refineries, chemical plants, power stations, and other types of manufacturing. Yet, using loop diagrams in the municipal water/wastewater sector is relatively new. The reasons for this are many-fold but usually can be traced to either individuals not knowing about them or perceiving that money can be saved by not creating them. This is changing as more water/wastewater utilities realize the initial and ongoing cost savings resulting from having

proper sets of loop diagrams or process loop sheets for constructing and troubleshooting facilities.

Benefits of loop diagrams. There are many benefits from taking the time to create loop diagrams during the detailed design phase of a project. A major benefit is the ability to identify and fix problems during the design phase rather

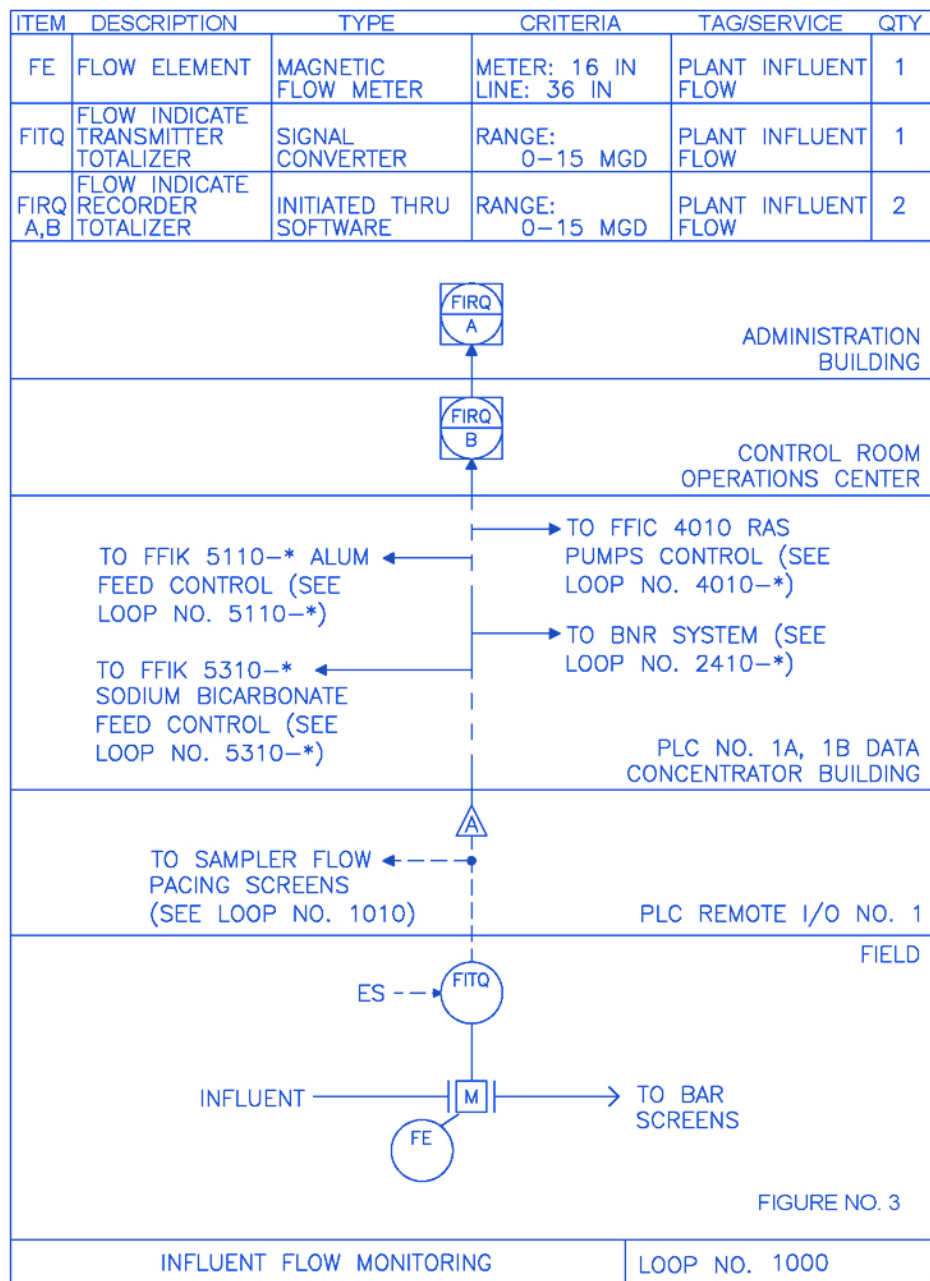


Figure 2. Example of a process loop sheet.

than during construction. It is significantly less expensive to sort out a design issue during the design phase (when it is easy to fix on paper) than during the construction of a facility.

Examples of potential design issues for process equipment include mismatched I/O signals, wrong power supply voltages, mis-ranged signal scaling, missing I/O signals, and missing installation details. These problems can cause delays and cost overruns when they must be fixed during a project's construction or commissioning phase.

In a typical capital project, it is not uncommon for an hour of work on-site during the construction phase to be up to 10 times more expensive than an hour of work during the paper-based design phase. Using a loop diagram during installation and maintenance can save thousands of dollars in terms of time savings and avoiding delays associated with investigation or troubleshooting.

For example, when installing a new motorized actuator with a loop diagram in hand, the electrical installation is as simple as hooking up the wires. The loop diagram provides a comprehensive guide for the installation electrician. The drawing will show what wires are needed, how to label them, and which I/O terminal screws to wire them to. The power connection details will also be shown. The loop diagram will also detail and summarize the voltages and scaling of all of the various signals.

If a loop diagram is not provided, the installation electrician will first have to search the PLC panel drawings to determine which I/O signals to wire to the actuator (if

the descriptions in the PLC panel are clear). Next, they must review the motor control center (MCC) or lighting panel schedules to determine the intended power source for the device. Then the electrician will need to find the installation manual for the actuator (often not shipped with the actuator), to match the various terminals on the actuator with the requested I/O signals and power connections.

Without a loop diagram, a simple 10-minute troubleshooting task can turn into hours of difficult trial-and-error troubleshooting to find the issue.

Because the design engineer has likely not looked at these signals together (i.e., there was no corresponding loop diagram to be subjected to QA/QC), often there will be minor I/O errors in the design. The electrician will need to resolve the errors on-site or issue a request for information (RFI) to the design team to obtain the necessary data. All of this is very time-consuming during the construction phase, and the contractors are under tremendous pressure to get the plant built.

Likewise, suppose an installed valve actuator requires troubleshooting. In an ideal situation, an as-built loop diagram or process loop sheet for the actuator will include all the information the maintenance electrician will need to check the power and signals to/from the actuator. (When a construction project is

completed, the design engineer will prepare an updated set of the contract drawings called “as-built” or “for record” that captures the details of what was actually built verses the initial plans.) However, suppose there is no loop diagram for the actuator. The electrician will have to search through PLC panel drawings, other drawings, and equipment manuals to determine how the actuator is wired and powered.

Often, if there are no loop diagrams, no drawing will exist that shows how the

terminal screws of the valve actuator have been wired and what the terminals and configuration do. Thus, without a loop diagram, a simple 10-minute troubleshooting task can turn into hours of difficult trial-and-error troubleshooting to find the issue.

Process loop sheets explained

Process loop sheets can take many forms. One common practice is to size the sheet to fit on US letter size (8.5" × 11") paper.

Multiple sheets can be grouped on a larger

24" × 36" contract drawing for larger projects. Another, used in other industries, is to make the process loop sheets the same size as other drawings used for the project, such as ANSI B or ISO A3.

Process loop sheets may be drawn by hand or produced in a drawing application such as AutoCAD (see Figure 3). On small projects, the sheets can easily be attached to the contract specification documents or placed

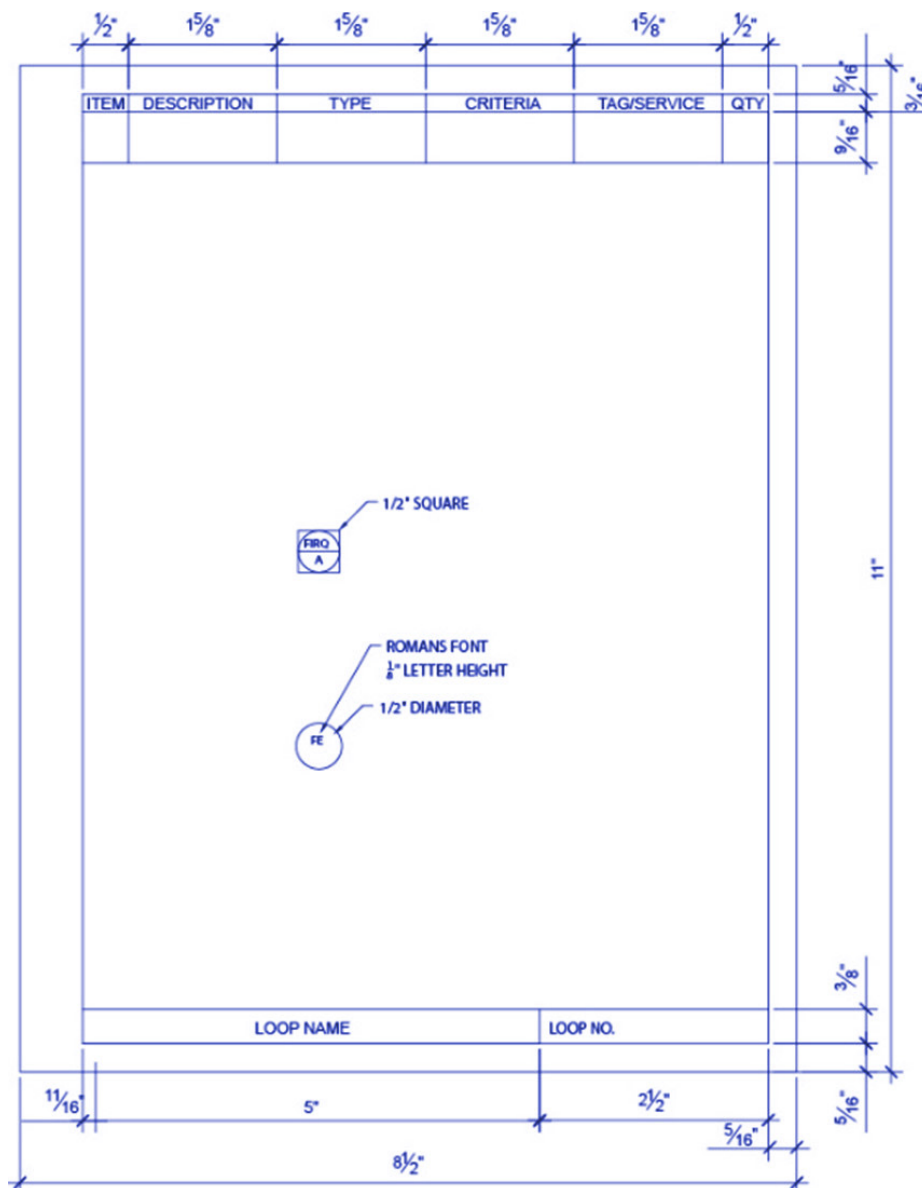


Figure 3. Example of a process loop sheet on 8.5" × 11" paper (portrait orientation).

typically defined in an end-user-specific standard. It is important to note that there are many of the same types of instruments. That is why each device and piece of equipment should be assigned a unique ID that is only used once at the plant. For example, ISA-5.1 provides a method of doing this using loop numbers, but each plant may have its own internal convention. The important takeaway is that the identifier must be unique.

- **Description.** This area explains the identifiers in the Item block. This block is valuable to anyone unfamiliar with ISA standard terminology and/or the plant's instrument/device tagging system.
- **Type.** This block provides details about each device. For example, it may identify a flow element (FE) as either a magnetic flow meter, a Venturi flow tube, or an ultrasonic flow meter.
- **Criteria.** This block contains requirements that are unique to the device or piece of equipment, such as the color of a pilot light lens, calibrated pressure, temperature, low-flow range requirements, elevations of level switches, and analysis analyzer ranges. This block or the Type block may also contain information indicating which contractor is responsible for providing the device or piece of equipment. If there are special installation or commissioning requirements that are unique to a particular instrument, these will sometimes be also included on the process loop sheet.
- **Tag/service.** This block is used to identify the item and what it does in the process. This is useful for an individual who does

not understand the process or plant requirements, as well as someone assembling a control panel who must identify each piece of equipment on the panel by the process that is either being controlled or monitored.

- **Quantity.** This is the number of items. For example, if multiple items of the same type are needed a quantity is listed rather than having multiple row entries. Likewise if similar, but slightly different, items are needed it is best to list them separately in separate rows.

Some call loop diagrams and process flow sheets “the instrumentation engineer’s gold mine” because they can result in considerable savings in the construction, installation, and commissioning phases of a project.

The example process loop sheet in Figure 4 shows that the influent flow meter sends a 4–20 mA signal via analog output to all devices throughout the diagram. In addition to providing a flow rate signal to the control system, the meter also records the average daily flow and keeps a 24-hour record, a process known as totalizing (denoted by the “Q” in the ISA-style identifier tag). The A and B labels on the FIRQ symbols indicate that the same information is transmitted to both devices, meaning that there are devices that

show the totalized flow in both the control room and the administration center.

The line types used on a process loop sheet are the same as those used on the process part of a loop diagram. That is, dashed lines for electrical signals and solid lines for piping. Figure 5 provides an overview of the line types commonly used to process loop sheets. The intent of using process loop sheets is to provide enough detailed information so that an installation electrician can know how to wire a piece of equipment and how it is used.

Further examples

Both loop diagrams and process loop sheets can range from simple to complex depending on the equipment (instrumentation, devices, control elements, etc.) they describe. The example of a complex loop diagram in Figure 6 is from ISA-5.4. It shows an orifice-plate-based flow transmitter (which uses a differential pressure transmitter to read the flow based on the pressure drop across an orifice plate) and a flow control valve on a pumped fill line to a tank.

The field I/O wiring passes through a junction box in a cable spreading room; there is another set of junction terminals at the rear of a panel;

then, there is a flow controller/PLC shown in a front-facing panel. Though showing older technology, the diagram in Figure 6 shows the amount of wiring/installation details that can be included on a loop diagram.

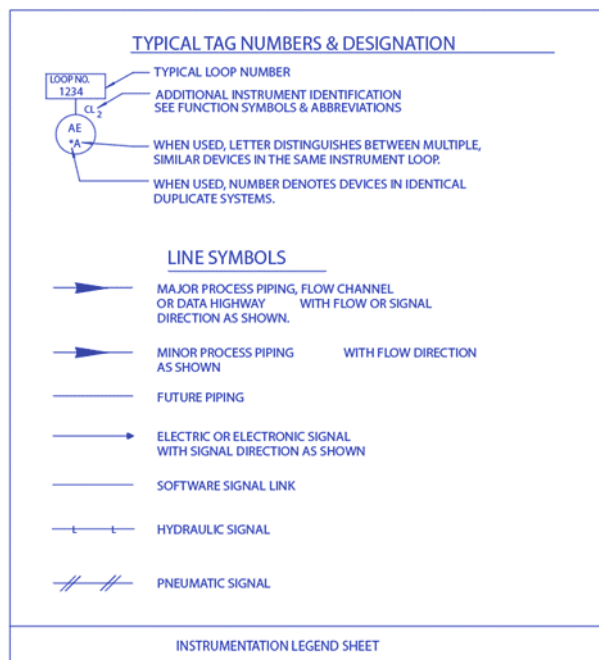


Figure 5. Commonly used line types on process loop sheets.

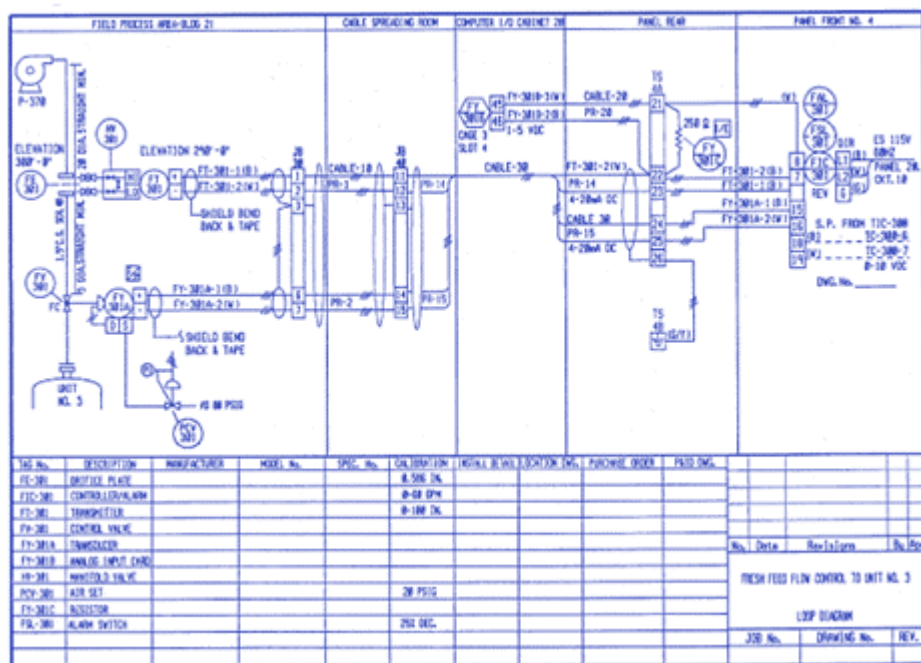


Figure 6. Example of a complex loop diagram.

Source: Figure 5 from ISA-5.4-1991. Reproduced with permission.

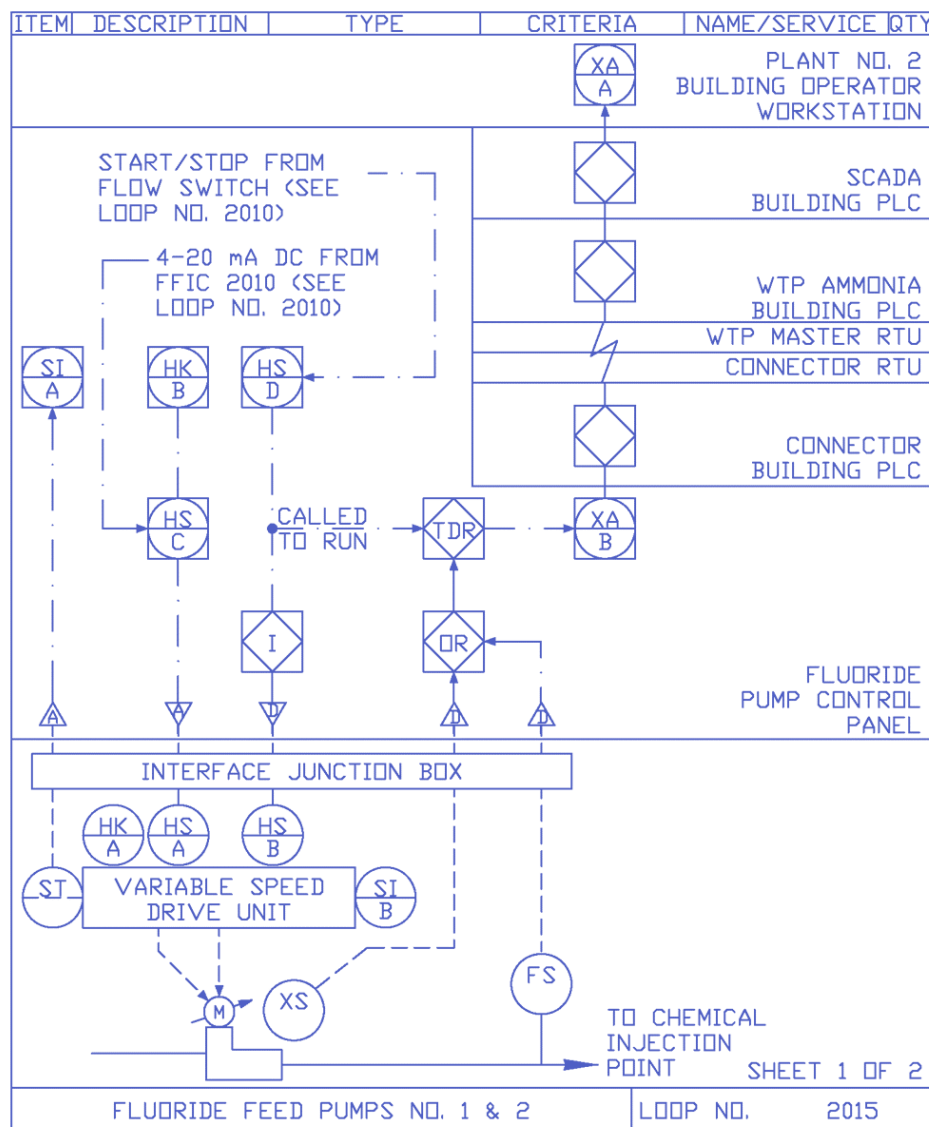


Figure 7. Example of a more complex process loop sheet.

Figure 7 shows a more complex process loop sheet. In this example, multiple I/O signals are wired to a chemical feed pump. The process loop sheet shows how the signals are wired from the pump to an interface junction box, to a fluoride system control panel, and then into a PLC system. Though it does not show the exact wire terminal details, it shows the flow of the signals so an installation or maintenance technician can easily see where the signals are being routed as part of the system.

Depending on the type and complexity of the project, it may be preferable to create a set of loop diagrams, a set of process loop sheets, or a combination of both. This will depend on the system designer and what they feel is necessary to provide clear instructions to the installation electrician for the system. Ideally, if both loop diagrams and process loop sheets are created, they can be used together to create an accurate account of how the system should be installed and how it has been installed once construction/commissioning is complete.

Summary

Loop diagrams and process loop sheets are two types of detail drawings that, though they take time to prepare, can result in considerable savings in the construction, installation, and commissioning phases of a project. These savings result from the installation electrician having clear instructions on how to wire and test the system instead of doing the detailed wiring design on-the-fly in the field as part of the construction process.

The production of loop diagrams and process flow sheets also makes it possible for many design issues to be seen and rectified during the design phase rather than during construction. Though there is a cost to prepare these drawings, the benefits of having them greatly outweigh the preparation cost. Hence, many instrumentation professionals refer to loop diagrams and process loop sheets as the “instrumentation engineer’s goldmine”—they are worth their weight in gold when undertaking a project.

ABOUT THE AUTHORS

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