6 Control System Documentation

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Topic Highlights

Reasons for Documentation
Types of Documentation
Process Flow Diagram (PFD)
Piping and Instrument Diagrams (P&IDs)
    Loop Numbering
Instrument Lists
Specification Forms
Logic Diagrams
Location Plans (Instrument Location Drawings)
Installation Details
Loop Diagrams
Standards and Regulations
    Mandatory Standards
    Consensus Standards
Operating Instructions

6.1 Reasons for Documentation

The documentation used to define modern control systems has evolved over the past 50 years. Its purpose is to impart, efficiently and clearly, to a knowledgeable viewer enough information so that the result is an operating plant producing the desired product. The documents described in this chapter form a typical set for use in the design of a continuous process plant. Some of the documents are also used in other process types. The typical set is not necessarily a standard set. Some designs may not include all of the described documents, and some designs include documents not described.

All of the illustrations and much of the description used in this section were published in 2004 by ISA in *Instrumentation and Control System Documentation* by Frederick A. Meier and Clifford A. Meier. That book includes many more illustrations and much more explanation.

ISA is the abbreviation for The Instrumentation, Systems, and Automation Society. For this reason, this section uses the term "automation and control" (A&C), rather than "instrument and control" (I&C) used in the Meiers' book to describe the engineers and designers developing the control system documentation.

6.2 Types of Documentation

Descriptions and typical sketches are included for the following:

- Process Flow Diagrams (PFD)
- Piping and Instrument Diagrams (P&ID)
- Loop Numbering
- Instrument Lists
- Specification Forms
- Logic Diagrams
- Location Plans (Instrument Location Drawings)
- Installation Details
- Loop Diagrams
- Standards and Regulations
- Operating Instructions

Figure 6-1, or the timeline, illustrates a possible sequence for document development. Information from one document is used to develop succeeding documents.

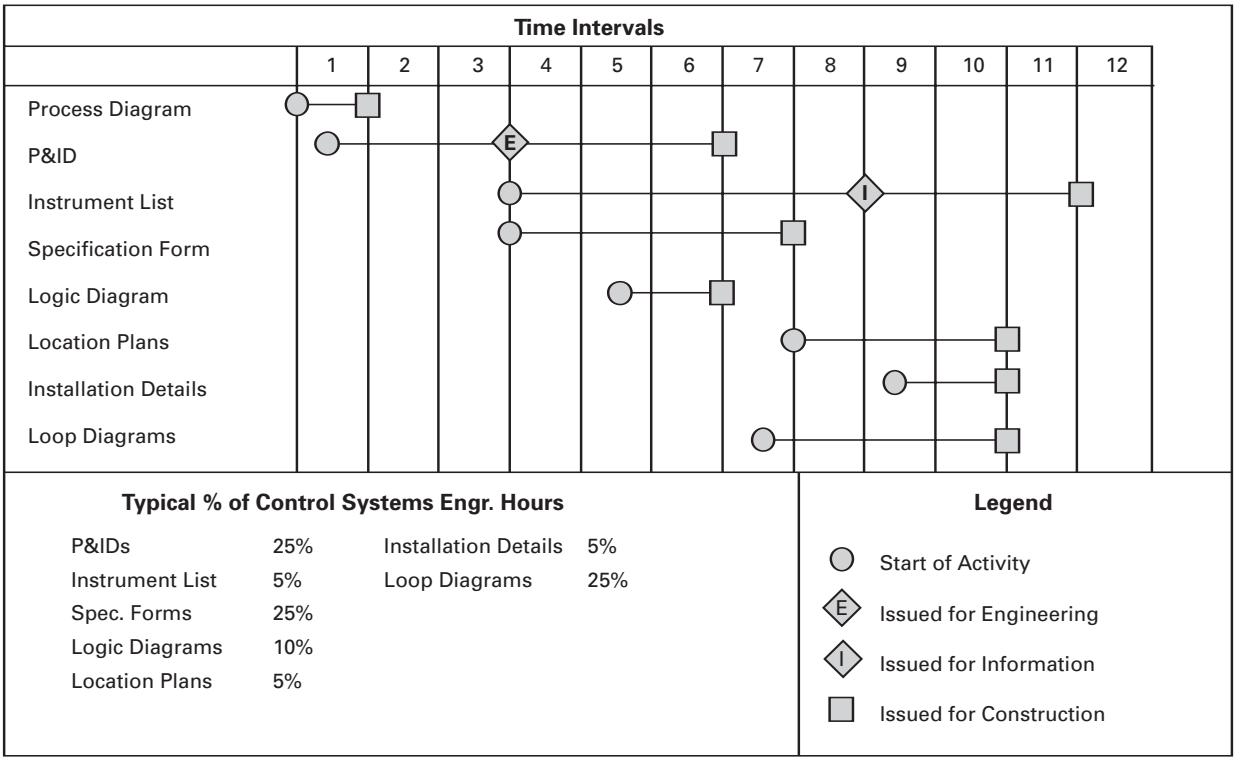


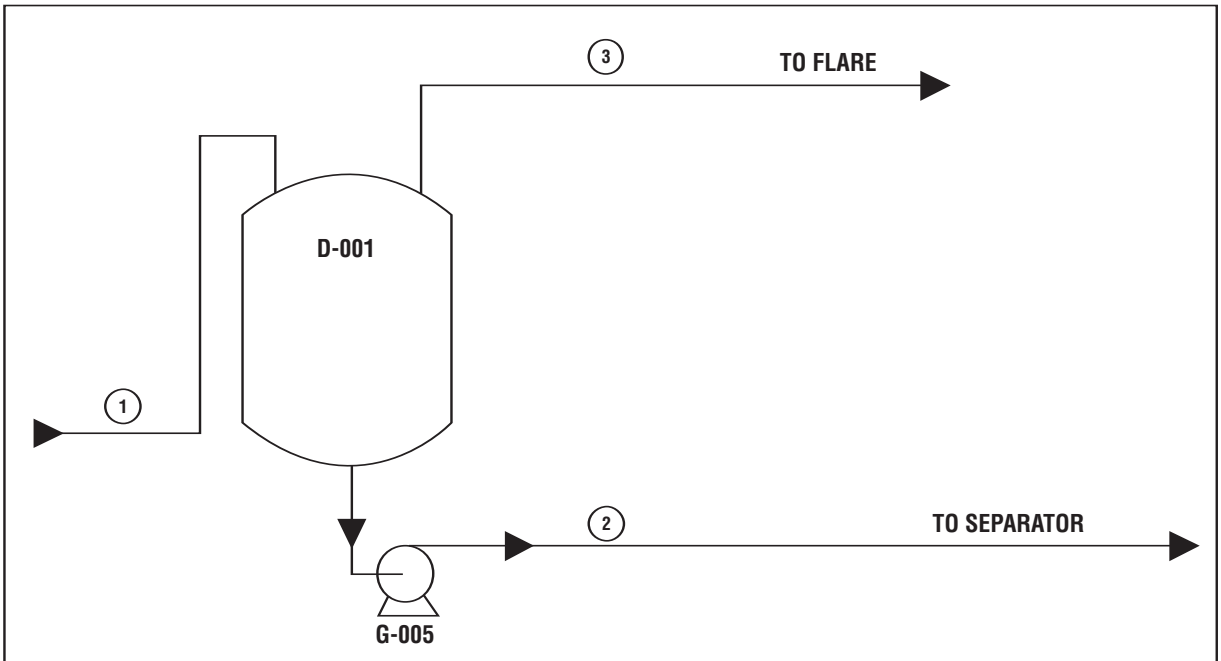
Figure 6-1: Instrument Drawing Schedule

The time intervals vary. The intervals might be days, weeks, or months, but the sequence remains the same. The documents listed are not all developed or used solely by a typical automation and control group (A&C). However, the A&C group contributes to, and uses, the information contained in them during plant design.

6.3 Process Flow Diagram (PFD)

A Process Flow Diagram defines a process schematically. PFDs are most valuable for continuous process chemical plants. The PFD shows what and how much of each product a plant might make; descriptions and quantities of the raw materials necessary; by-products produced; critical process conditions—pressures, temperatures, and flows; necessary equipment; and major process piping.

Figure 6-2 shows a simple PFD of a knockout drum, which separates the liquid from a wet gas stream. Process engineers frequently produce PFDs. Some PFDs include basic, important—or high-cost—A&C components. There is no ISA standard for PFDs, but ISA-5.1-1984 (R1992) *Instrument Symbols and Identification* and ISA-5.3-1983 *Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic, and Computer Systems* contain symbols that can be used to show A&C components.



STREAM NUMBER	FLOW	DESCRIPTION	TEMP	PRESSURE	SP GRAVITY
1	10,000#/Hr	WET GAS	90° - 180° F	20 psi	-
2	1,000#/Hr	DEGASSED MATERIAL	70° - 170° F	50 psi	0.9 AT 60°F
3	9,000#/Hr	LIGHT ENDS TO FLARE	80° - 140° F	4 psi	-

ISA COURSE FG15
PROCESS FLOW DIAGRAM
PLANT 001 KNOCKOUT DRUM 0-001
DRG #PFD-1

Figure 6-2: Process Flow Diagram

Batch process plants may configure their equipment in various ways, as raw materials and process parameters change. Many different products are often produced in the same plant. A control recipe, or formula, is developed for each product. A PFD may be developed for each recipe.

6.4 Piping and Instrument Diagrams (P&ID)

The acronym P&ID is widely understood within the process industries to mean the principal document used to define the process—the equipment, piping, and all A&C components. ISA's *Automation, Systems, and Instrumentation Dictionary* definition for P&ID tells us what they do. P&IDs "show the interconnection of process equipment and instrumentation used to control the process."[1]

P&IDs are developed in steps by members of the various design disciplines as a project proceeds. Information placed on a P&ID by one discipline is used by other disciplines as the basis for their design.

The P&ID shown in Figure 6-3 has been developed from the PFD in Figure 6-2. The P&ID includes the control system definition using symbols from ISA-5.1 and 5.3. There are two electronic loops which are part of the shared display/distributed control system (DCS): FRC-100, a flow loop with control and recording capability, and LIC-100, a level loop with control and indicating capability. There is one field-mounted pneumatic loop, PIC-100, with control and indication capability. There are several switches and lights on a local (field) mounted panel, including hand operated switches and lights HS and ZL-400, HS and HL-401, and HS and HL-402. There are other control system components shown, in addition to the above. The P&ID now includes more piping and mechanical equipment details.

6.4.1 Loop Numbering

Letter designations and tag numbers identify all A&C components. All devices in a loop have the same tag number but different letter designations.

Figure 6-4 consists of LT-100, a field mounted electronic transmitter; LI-100, a field mounted electronic indicator; LIC-100, a level controller which is part of the DCS; LY-100, a current-to-pneumatic (I/P) converter; and LV-100, a pneumatic butterfly control valve. ISA-5.1 states that loop numbers may be parallel, requiring a new number sequence for each process variable, or serial, using a single numeric sequence for all process variables. Figure 6-3: P&ID uses a parallel numbering system. There is a flow loop FRC-100, a level loop LIC-100, and temperature loop TI-100. The level gauges, pressure gauges, and thermometers all are numbered starting with 1: LG-1, PI-1, TI-1.

Figure 6-5 shows how tag marks may also identify the loop location or service. Other numbering systems are used that tie instruments to a P&ID, a piece of equipment or a location.

6.5 Instrument Lists

The Instrument List (or instrument index) is an alphanumeric listing of all tag-marked components. Each tag mark will reference the relevant drawings and documents for that device.

Figure 6-6 is a partial listing which includes the level devices on D-001—K.O. drum: LG-1, level gauge; LT-100, level transmitter; and LI-100, level indicator (all from Figure 6-3: P&ID). In addition, the list shows other instruments on other P&IDs, not included. Figure 6-6 has six columns—for P&ID, Spec Form, Req. #, Location Plan, Installation Detail, and Piping Drawing.

The Instrument List is developed by the A&C group. There is no ISA standard defining an Instrument List. With the advent of computer-aided design techniques, the Instrument List may contain a large number of columns for various uses during project design, construction, and operation.

6.6 Specification Forms

The A&C group defines the tag-marked devices so suppliers may quote and supply the correct device. A Specification Form (or data sheet) is filled out for each device.

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1. *The Automation, Systems, and Instrumentation Dictionary,* 4th edition (ISA, 2003), pg. 273.

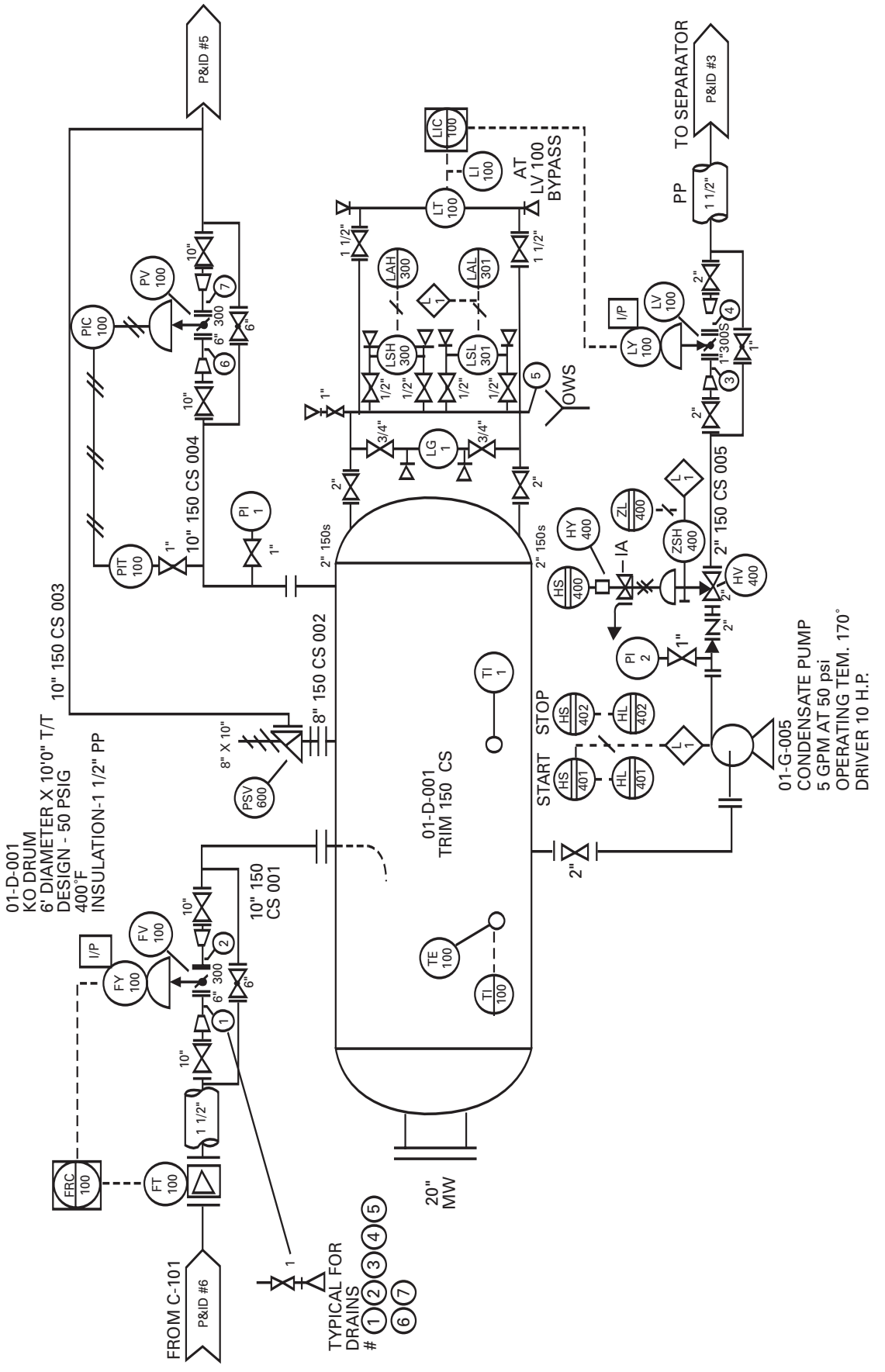


Figure 6-3: P&ID

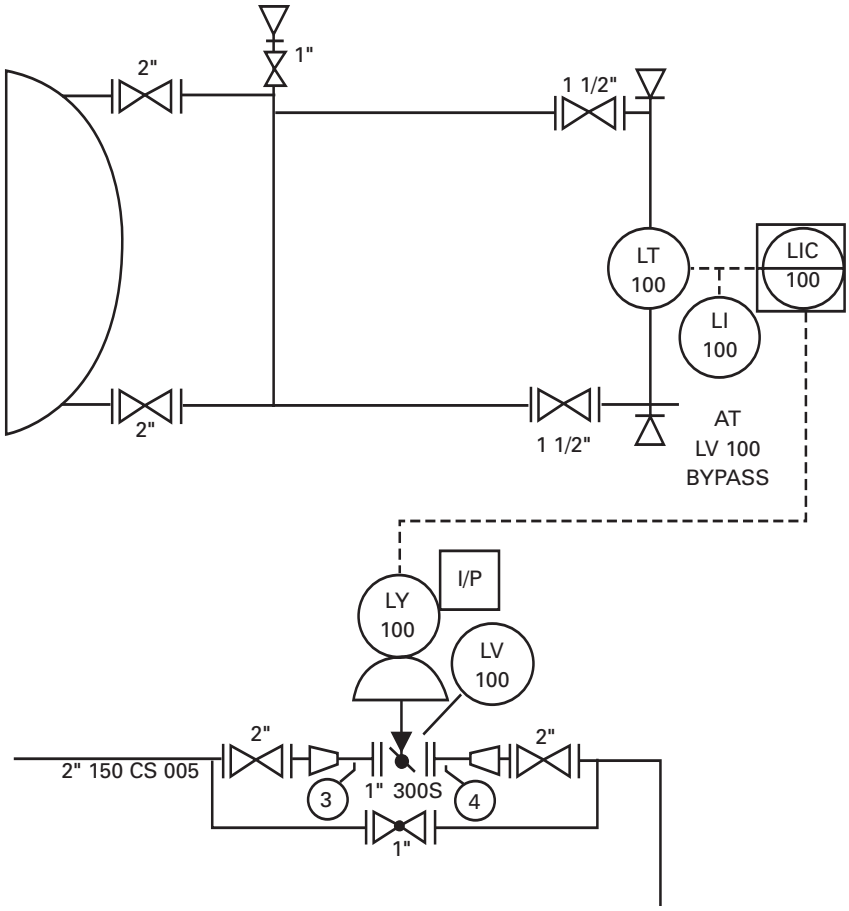


Figure 6-4: Level Loop LIC-100

- **Use Basic Number if project is small and there are no area, unit, or plant numbers:**
  - Basic Number FT-2 or FT-02 or FT-002
- **If project has a few areas, units, or plants (9 or less), use the first digit of the plant number as the tag number:**
  - FT-102 (1 = area, unit, or plant number)
- **If project is divided into area, units, or plants:**
  - 1-FT002
  - 01-FT002
  - 001-FT002

Figure 6-5: Instrument Numbering

Let's look at LT-100 from Figure 6-3. The P&ID symbol defines it as an electronic displacement-type level transmitter.

Figure 6-7 is the completed Specification Form for LT-100. This form is from ISA-20-1981, *Specification Forms for Process Measurement of Control Instruments, Primary Elements and Control Valves*. There are many variations of Specification Forms. Most engineering contractors have developed a set, some control component suppliers have their set, and ISA has another newer set in technical report, ISA-

Tag #	Desc.	P&ID #	Spec Form #	REQ #	Location Plan #	Install. Detail	Piping Drawing
LG-1	D-001-K.O. Drum	1	L-1	L-1	—	—	ISO-010
LG-2	D-001 Distil. Column	2	L-1	L-1	—	—	ISO-015
LG-3	C-002 Stripper	3	L-1	L-1	—	—	ISO-016
LT-100	D-001 K.O. Drum	1	L-100	T-1	LP-1	ID-001	ISO-010
LI-100	D-001 K.O. Drum	1	I-100	I-1	LP-1	ID-002	—
LT-101	C-001- Distil. Column	2	L-100	T-1	LP-4	ID-001	ISO-015
LT-102	C-002 Stripper	3	L-100	T-1	LP-5	ID-001	ISO-016

Figure 6-6: A Typical Instrument List

TR20.00.01-2001, *Specification Forms for Process Management & Control - Part 1: General Considerations*. The purpose of all of the forms is to aid the A&C group to organize the information needed to fully and accurately define control components so they may be quoted on, and supplied, by vendors. Specification Forms are filled out by the A&C group. Their development is a significant part of the group's effort.

6.7 Logic Diagrams

Continuous process control is shown clearly on P&IDs. Different presentations are needed for on/off control. Logic Diagrams are one form of these presentations. ISA's set of symbols are defined in ISA-5.2-1976(R1992) - *Binary Logic Diagrams for Process Operations*.

ISA symbols AND, OR, NOT and MEMORY (FLIP-FLOP) with an explanation of their meaning are shown in Figures 6-8 and 6-9. Other sets of symbols and other methods may be used to document on/off control. Some examples: text descriptions, a written description of the on/off system; ladder diagrams; or electrical elementaries.

Some designers develop a Functional Specification or Operation Description to document the entire system. These documents usually include a description of the on-off control of the process.

A motor start circuit is shown in Figure 6-10 in ISA logic form and also by an elementary diagram.

6.8 Location Plans (Instrument Location Drawings)

There is no ISA standard that defines a Location Plan or an Instrument Location Drawing. Location Plans show the location and elevation of control components on plan drawings of a plant.

Figure 6-11 shows one approach for a Location Plan. It shows the approximate location and elevation of the tag-marked devices included on the P&ID, Figure 6-3, air supplies for the devices, and interconnection tubing needed to complete the pneumatic loop. Other approaches to Location Plans might include conduit and cabling information and fitting and junction box information. Location Plans are developed by the A&C or electrical groups. They are used during construction and by maintenance personnel after the plant is built to locate the various devices.

			LEVEL INSTRUMENTS (DISPLACER OR FLOAT)				SHEET		OF	
							SPEC. NO.		REV.	
			NO	BY	DATE	REVISION	321		0	
			0	FAM	12/15/2003		CONTRACT		DATE	
							1234			1/3/2003
							REQ. - P.O.			
							J-6 J-12			
							BY	CHK'D	APPR.	
							FAM	CHK CAM	LF	
	1	Tag Number	LT-100							
	2	Service	K.O. DRUM							
	3	Line Number / Vessel Number	01-D-001							
	4	Body or Cage Material	C.S.							
		Rating	300 psi							
	5	Conn Size & Location Upper	1 1/2" TOP							
		Type	300 psi FLG							
	6	Conn Size & Location Lower	1 1/2" BTM							
		Type	300 psi FLG							
BODY/CAGE	7	Case Mounting	SIDE							
		Type								
	8	Rotatable Head	NOT REQ							
	9									
	10	Orientation	LEFT HAND							
	11	Cooling Extension	NOT REQ							
	12									
	13	Dimensions	48"							
	14	Insertion Depth								
DISPLACER	15	Displacer Extension								
OR FLOAT	16	Disp. or Float Material	304 S.S.							
	17	Displacer Spring/Tube Mtl.	MFG. STD.							
	18									
	19									
	20	Function	TRANSMITTER							
	21	Output	4-20 mAdc							
	22	Control Modes								
	23	Differential								
XMTR/CONT.	24	Output Action: Level Rise	INCREASE							
	25	Mounting	INTEGRAL							
	26	Enclosure Class	NEMA 8							
	27	Elec. Power or Air Supply	24Vdc from shared							
	28		display							
	29	Upper Liquid	WET GAS							
	30	Lower Liquid	DEGASSED MTL.							
	31	Sp. Gr.: Upper	Sp. Gr.: Lower		.9 @ 60 F					
SERVICE	32	Press. Max.	Normal	50 PSI	4 PSI					
	33	Temp. Max.	Normal	400 F	90-150 F					
	34									
	35									
	36	Airset	Supply Gage							
	37	Gage Glass Connections								
	38	Gage Glass Model No.								
	39	Contact: No.	Contact: Form							
OPTIONS	40	Contact Rating								
	41	Action of Contacts								
	42									
	43									
	44									
	45									
	46	Manufacturer	LATER							
	47	Model Number	LATER							
	48									

NOTES:

 ISA FORM S20.26

Figure 6-7: Level Instrument - Specification Form

6.9 Installation Details

Installation Details define the requirements to correctly install the tag-marked devices. The Installation Details show process connections, pneumatic tubing, or conduit connections, insulation and winteriz-

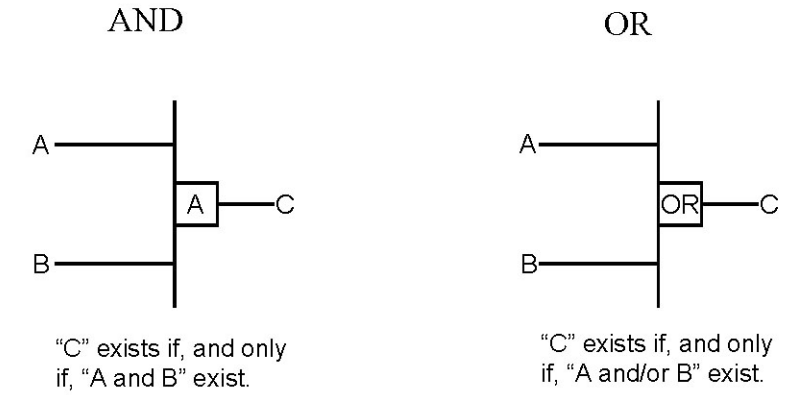


Figure 6-8: Binary Logic Symbols - AND & OR

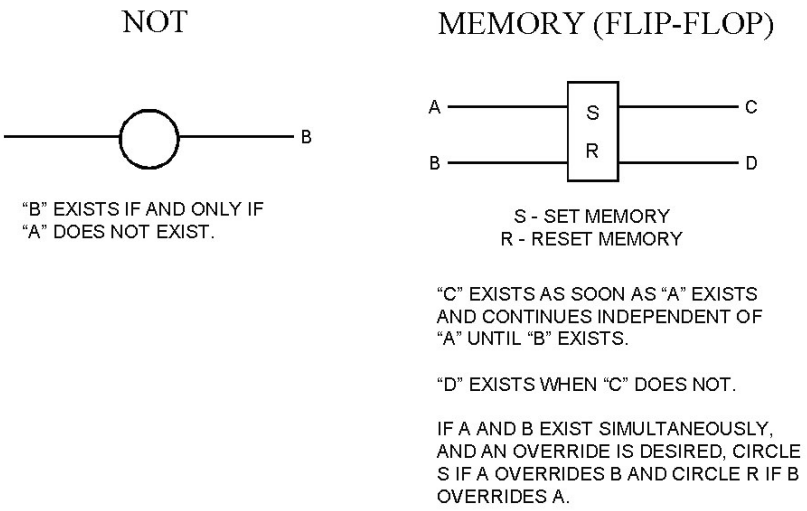


Figure 6-9: Binary Logic Symbols - NOT & MEMORY (FLIP-FLOP)

ing requirements, and support methods. There is no ISA Standard that defines Installation Details. However, libraries of Installation Details have been developed and maintained by engineering contractors, A&C device suppliers, some plant owners, installation contractors, and some individual designers. They all have the same aim—successful installation. They may differ in details as to how to achieve it, however.

Figure 6-12 shows one approach. This drawing includes a material list to aid in procuring installation materials and assisting installation personnel.

Installation Details may by developed by the A&C group during the design phase. However, they are sometimes developed by the installer during construction or by an equipment supplier for the project.

6.10 Loop Diagrams

ISA's *Automation, Systems, and Instrumentation Dictionary* defines a Loop Diagram as "a schematic representation of a complete hydraulic, electric, magnetic or pneumatic circuit."[1] The circuit is called a loop. For a typical loop see Figure 6-4. ISA-5.4-1991, *Instrument Loop Diagrams* presents six typical loop dia-

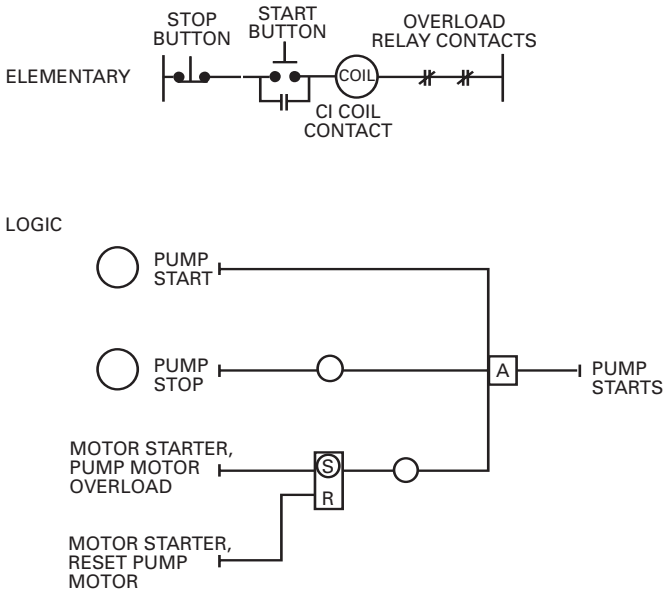


Figure 6-10: Motor Start Logic

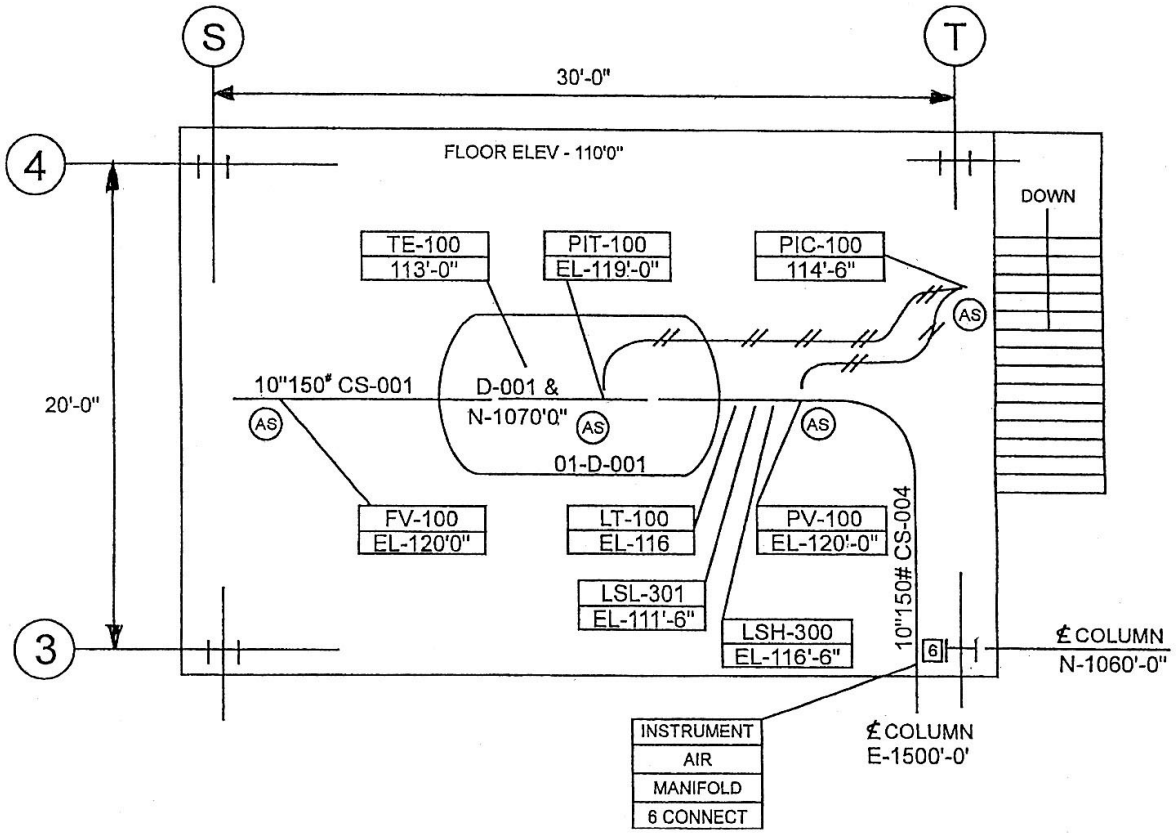


Figure 6-11: Location Plan, Approach A

1. Ibid., pg. 299.

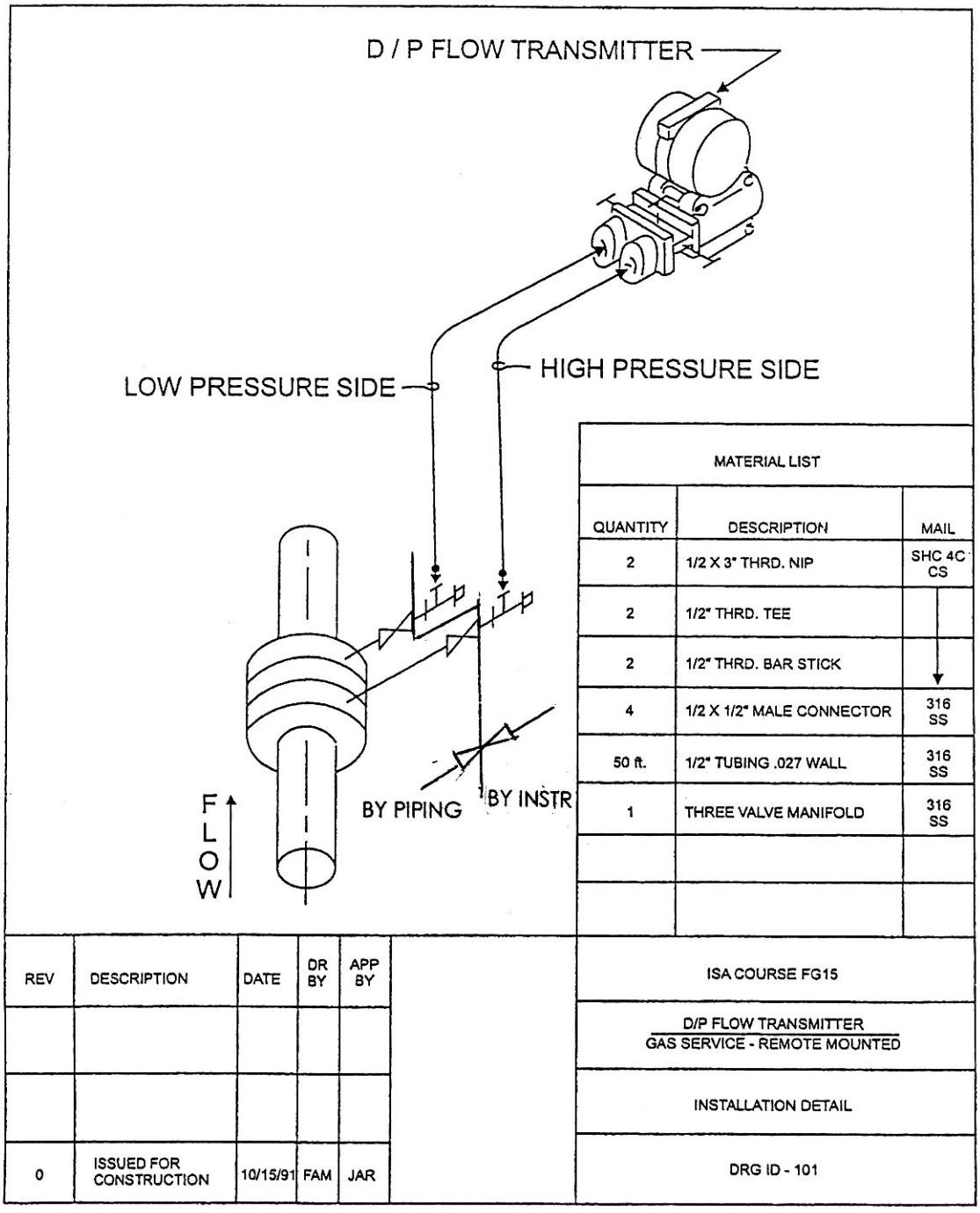
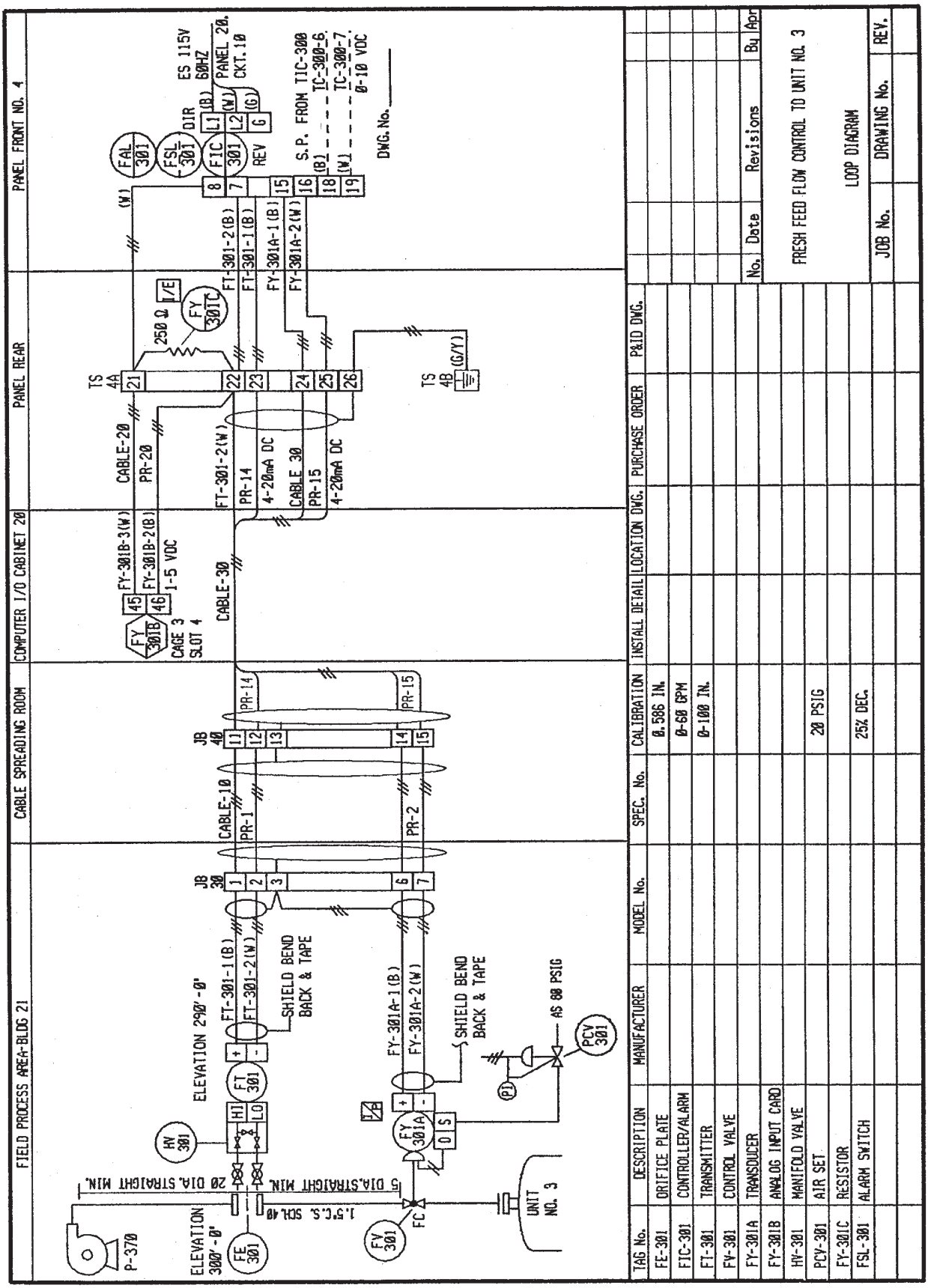


Figure 6-12: Installation Detail, Type 2 - Flow Transmitter

grams, two each for pneumatic, electronic, and distributed control (DCS). One of each type shows the minimum items required, and the other shows additional optional items.

Figure 6-13 is a Loop Diagram for electronic flow loop FIC-301. Loop Diagrams are not always included in a design package. Some plant owners do not believe they are worth their cost, which is significant. Loop Diagrams are sometimes produced by the principal project A&C supplier, the installation contractor, or by the plant owner's operations, maintenance, or engineering personnel. Sometimes Loop Diagrams are produced on an “as needed” basis after the plant is running.



TAG No.	DESCRIPTION	MANUFACTURER	MODEL No.	SPEC. No.	CALIBRATION	INSTALL DETAIL	LOCATION DWG.	PURCHASE ORDER	P&ID DWG.
FE-301	ORIFICE PLATE				8.586 IN.				
FIC-301	CONTROLLER/ALARM				0-60 GPM				
FT-301	TRANSMITTER				0-100 IN.				
FV-301	CONTROL VALVE								
FY-301A	TRANSDUCER								
FY-301B	ANALOG INPUT CARD								
HV-301	MANIFOLD VALVE								
PCV-301	AIR SET				20 PSIG				
FY-301C	RESISTOR								
FSL-301	ALARM SWITCH				25% DEC.				

No.	Date	Revisions	By	Apr

FRESH FEED FLOW CONTROL TO UNIT NO. 3

LOOP DIAGRAM

JOB No.	DRAWING No.	REV.

Figure 6-13: Loop Diagram, Electronic Control, Minimum Required Items Plus Optional Items

6.11 Standards and Regulations

6.11.1 Mandatory Standards

Federal, state, and local laws establish mandatory requirements: codes, laws, regulations, requirements, etc. The Food and Drug Administration issues Good Manufacturing Practices. The National Fire Protection Association (NFPA) issues Standard 70, the *National Electric Code* (NEC). The United States government manages about 50,000 mandatory standards. The Occupational Safety and Health Administration (OSHA) issues many regulations including government document 29 CFR 1910.119, *Process Safety Management of Highly Hazardous Chemicals* (PSM). There are three paragraphs in the PSM which list documents required if certain hazardous materials are handled. Some of these documents require input from the plant A&C group.

6.11.2 Consensus Standards

Consensus Standards include recommended practices, standards, and other documents developed by professional societies and industry organizations. The standards developed by ISA are the ones used most often by A&C personnel. Relevant ISA standards include: ISA-5.1-1984-(R1992), *Instrumentation Symbols and Identification*, which defines symbols for A&C devices; ISA-5.2-1976-(R1992), *Binary Logic Diagrams for Process Operations*, which provides additional symbols used on Logic Diagrams; and ISA-5.3-1983, *Graphic Symbols for Distributed Control/ Shared Display Instrumentation, Logic and Computer Systems*, which contains symbols useful for DCS definition. The key elements of ISA-5.3 are now included in ISA-5.1, and ISA-5.3 will be withdrawn in the future.

ISA-5.4 *Instrument Loop Diagrams* includes additional symbols and six typical instrument Loop Diagrams. ISA-5.5 *Graphic Symbols for Process Displays* establishes a set of symbols used in process display. Other ISA standards of interest include ISA-20-1981, *Specification Forms for Process Measurement and Control Instruments, Primary Elements and Control Valves*. ISA TR20.00.01-2001, *Specification Forms for Process Control and Instrument, Part 1: General Considerations*, updates ISA-20. ANSI/ISA-84.00.01-2004 - *Functional Safety: Safety Instrumented Systems for the Process Industry Sector*, defines the requirements for safe systems. ANSI/ISA-88.01-1995, *Batch Control Part I Models and Terminology*, shows the relationships involved between the models and the terminology.

In addition to ISA, other organizations develop documents to guide professionals. These organizations include American Petroleum Institute, American Society of Mechanical Engineers, National Electrical Manufacturers Association, Process Industry Practice, and Technical Association of the Pulp and Paper Industry.

6.12 Operating Instructions

Operating Instructions are necessary to operate a complex plant. They range from a few pages describing how to operate one part of a plant to a complete set of books covering the operation of all parts of a facility. They might be included in a functional specification or an operating description. There is no ISA standard to aid in developing Operating Instructions. They might be prepared by a group of project, process, electrical and A&C personnel during plant design. Some owners prefer plant operations personnel to prepare these documents. The Operating Instructions guide plant operators and other personnel during normal and abnormal plant operation, including start-up, shutdown, and emergency operation of the plant.

OSHA requires operating procedures for all installations handling hazardous chemicals. Their requirements are defined in government document 29 CFR 1910.119(d) *Process Safety Information*, (f) *Operating Procedures* and (l) *Management of Change*. For many types of food processing and drug manufacturing, the Food and Drug Administration issues Good Manufacturing Practices.

About the Author

Fred Meier's career in engineering and engineering management spans 50 years. He has been an active member of ISA for more than 40 years. He has earned an ME from Stevens Institute of Technology and an MBA from Rutgers University and has held Professional Engineer licenses in the United States and in Canada. Fred and his son, Clifford, are authors of *Instrumentation and Control System Documentation* published by ISA in 2004. He and his wife Jean live in Chapel Hill, NC.