ENGINEERING AND CONSTRUCTION STANDARD

FOR

PROGRAMMABLE LOGIC CONTROLLERS (PLC)

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PART 1

ENGINEERING STANDARD

FOR

PROGRAMMABLE LOGIC CONTROLLERS (PLC)

0. INTRODUCTION

In this Standard, the following conceptual control levels has been assumed; levels 3 through 7 is for ESD, and levels 1 and 2 are considered for sequential and batch control.

Level 1

Level 1 system is not emergency shut-down and will be considered for sequential control system.

Level 2

Level 2 system is not emergency shut-down and will be considered for batch control system.

Level 3

A level 3 shut-down would occur when on upset condition on a single unit requires that unit to be shut-down with no other unit affected and the rest of process continues the stable operation with no loss of production. This level of control is the last chance which prevents damage to the process, personnel or any other type of hazards.

Level 4

A level 4 shut-down would occur if an upset in one system directly causes the shut down of one or more parts of the system. This level of shut-down would cause the loss of production from one production train.

Level 5

Level 5 shut-down are initiated by external non-process conditions, such as; feed stop to the plant, fuel stop to the plant system, or output stopage of the plant.

Level 6

Level 6 shut-downs would be initiated by external non-process factors, such as; gas detection in a safe area, main and emergency power generating equipment stoppage, AC circuits of uninterruptible power supplies (UPS) inverters stoppage and some DC important systems switching off, etc.

Level 7

A level 7 shut-down involves the shut down of every electrical system and the isolation of every battery with exception of the fire water pump start and control batteries. This level of shut-down is only considered during major gas leaks, blowouts, etc., where there is a danger that most of the installation will be covered by a gas cloud. Initiation of a level 7 shut-down will be performed by manual Emergency Shut-down Switch by the operator.

1. SCOPE

This Standard covers the minimum requirements and specific constraints to be fulfilled in engineering activities and procedures in designing Programmable Logic Controllers (PLC) for Iranian Petroleum Industries projects, including:

- Application of PLC for ESD system

- Application of PLC for sequential control and batch process control, which uses the upper levels of PLC application (levels 1 and 2 as described in introduction heretofore).

- Application of PLC for interlocking including safety circuits.

This Engineering Standard shall be applied in conjunction with IPS-E-IN-260 "Indicating Lights, Alarms and Protective Systems".

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor.

NEMA (NATIONAL ELECTRICAL MANUFACTURER'S ASSOCIATION)

ICS 3-304	"Programmable Controllers" (1988)

EIA (ELECTRONIC INDUSTRIES ASSOCIATION)

RS-232-C	"Standard Interface Between Data Equipment and Data Communication Equipment Employing Serial Binary Data Interchange"

ANSI (AMERICAN NATIONAL STANDARD INSTITUTE)

Y 32.14	"Graphic Symbols for Logic Diagrams-1962"

MIL-STD-806B

X 3.28	"Procedures for the Use of the Communication Control Characters of ASCII in Specified Data Communication Links" (1986)
ANSI/EIA 310C	"Racks, Panels and Associated Equipment" (1983)
ANSI/IEEE 91	"Graphic Symbols for Logic Functions" (1984)

IEC (INTERNATIONAL ELECTROTECHNIQUE COMMISSION)

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3. GENERAL ENGINEERING REQUIREMENTS

3.1 System Design Considerations

3.1.1 PLC's considered for emergency shutdown system shall be either dual redundant or two-out-of-three (triple redundant) configuration in order to increase availability and decrease the risk of system outage in a manner that a single failure within PLC does not jeopardize plant safety.

3.1.2 The PLC system voltage supply shall be considered to be 110 V ac or 24 V dc as specified in the project data sheets.

3.1.3 The field switches power supply system shall be considered either 110 V dc or 24 V dc as required in the specific project. If 110 V dc power supplies are employed then all field switches shall be specified to be explosion-proof type. Intrinsically safe system shall be considered in conjunction with 24 V dc power supplies.

3.1.4 All factors likely to cause the PLC breakdown should be identified and design precautions shall be taken to eliminate all weaknesses, in order to ensure reliable PLC operation in ESD or trip system application. The PLC system shall have a reliable fail-safe configuration, in addition to redundancy for all inputs, logic, power supplies, outputs, and communication hardware.

3.1.5 For plants with identifiable process areas, each capable of operating as independent unit, the process areas shall be categorized by nature of operation, size, hazard and location and each category shall be allocated with it's independent trip system. The plant's "trip system" therefore shall consist of a number of independent smaller systems, reflecting the plant's independent process areas.

3.1.6 Vendor shall be requested to provide a detailed "failure mode and effects" analysis to be evaluated for compliance with the project requirements.

3.1.7 In designing the PLC "elementary diagram" and subsequently selecting the manufacturer and sizing the PLC, the scan time shall be carefully considered.

3.1.8 In case that, the logic diagrams involved requires scan time that can not be met by single PLC, then distributed Networking of PLC shall be considered.

3.1.9 In case that, a single input or output requires faster scan time than the PLC, then PLC system shall be considered to have special instructions that interrupt normal scan and produce an immediate update on I/O.

3.1.10 It should be noted that the redundancy shall be of Hardware Implemented Fault Tolerant (HIFT) type with; fast switch-over time, software simplification, and tractable failure analysis.

3.1.11 PLC's with suitable configuration may be considered for sequence and batch control systems as detailed in article 8.0.

3.1.12 Consideration shall be given to the temperature, size caused by beat from the power supplies, memories, etc., which will produce excessive temperature inside the cabinet. In such condition inside temperature may be driven 10 to 20°C higher than environmental temperature. Therefore, if ambient temperature reaches above 40 to 45°C, special cooling shall be installed for the PLC equipment.

3.1.13 For inductive load inputs, a capacitor across the secondary side of the disconnect switch supplying power to the inductive load shall be provided for outrush problem.

3.2 Drawing Requirements

3.2.1 For each project, detailed logic sequence shall be designed and prepared by the engineering body in charge of the system design with "ladder diagram" representation. Symbols used in preparation of ladder diagram shall be selected of those listed in Appendix A.

3.2.2 In specifying the PLC for each project the above mentioned logic diagrams shall be prepared and attached to the IPS-M-IN-290 in addition to any specific technical requirements.

3.2.3 An I/O list shall be prepared by the engineering body amended to the specification sorted according to the type of I/O (i.e. discrete, digital, analog, etc.).

3.2.4 For batch and sequence control applications, in addition to the above documents, "timing diagrams" shall also be prepared for the project.

4. SIZING AND SELECTION OF INPUT/OUTPUT

4.1 I/O Selection

In addition to I/O selection criteria interfaces and peripherals are also discussed in this section.

4.1.1 Discrete I/O

4.1.1.1 Low impedance discrete I/O shall be selected for typical slow acting inputs.

4.1.1.2 High impedance input modules of TTL or ECL technology shall be selected for faster inputs depending on the time response requirements. When these types of Input module are selected, attention shall be paid to the wiring runs considering the noise interference problems.

4.1.1.3 Field connections shall be considered via; screw terminal blocks, connector cable assemblies, or other type of quick disconnect connectors according to the specific application.

4.1.1.4 Intelligent I/O modules shall be considered in applications where single PLC can not meet the scan time requirements. In this case, single I/O unit shall be considered far each process area, as far as practical.

4.1.1.5 It is desirable to have limited variety of I/O interfaces cards from the spare and diagnostics view point. On the other hand employing only a single size module would cause either unused I/O's, or produce a considerably bulkier interface system, which in both cases it will probably result in mismatched and more costly system.

4.1.2 I/O feature checklist

The following checklist are some important features to be considered for evaluating PLC system, as a minimum and should be indicated by Vendor.

- Total I/O count
- Discrete I/O count
- Analog I/O count
- Digital word I/O count
- Special I/O count
- Limit on overall mixture of discrete, analog, digital oriented, and special I/O's

4.1.2.1 Total I/O count and distribution

This item shall establish; the overall capability of the system (as defined primarily by the processor/language combination) and secondarily the limits on the system configurations (that may apply when mixing, discrete, word-oriented, and special type I/O).

4.1.2.2 Discrete I/O

This item shall be considered to verify the variety of discrete input and output signals that can be handled as well as any restriction in terms of processing or physical accommodation. The following subjects shall be verified in evaluation for discrete inputs and outputs.

a) Inputs

1) Voltage types available
2) Status indicators on the module
3) Isolation between inputs on each module type
4) Number of points per module options
5) Modules, per rack or cabinet

b) Outputs

1) Contact types available
2) Voltage types
3) Power or current limits
4) Status indicators on the module
5) Output protection
6) Isolation between outputs on each module type
7) Points per module options
8) Modules per rack or cabinet

4.1.2.3 Analog I/O

The following points shall be verified in evaluation.

a) Inputs

1) Voltage/current ranges available
2) Range of control softwares available on the PLC system
3) Single/double-ended input availability
4) Points per module
5) Mixed ranges available in modules
6) Internal calibration capability
7) Resolution
8) Updating times

b) Outputs

1) Voltage/current ranges
2) Points per module
3) Mixed outputs capability within modules
4) Calibration capability
5) Resolution of outputs

4.1.2.4 Word or register-oriented I/O

a) Inputs

1) Voltage ranges
2) Bits available per word
3) Bits available per module
4) Strobed (multiplexed) availability for inputs
5) Updating time
6) Time slots between strobed channels

b) Outputs

1) Voltage ranges
2) Bits available per word
3) Bits available per module
4) Strobed outputs availability
5) If strobed, is there a single-channel option?
6) Refresh time
7) Time-Slots between strobed channels

4.1.2.5 Special I/O

a) ASCII output

1) Limits to message sizes
2) Baud rates available
3) Rate change under software control
4) Connection type (RS 232, RS 422 or 20 mA loop)
5) Simplex or duplex (should be duplex)

b) Counter input

1) Voltage range
2) Maximum rate
3) Up/down count availability

c) Thermo-Couple input

1) Number of points
2) Cold junction compensation capability
3) Linearization capability

d) RTD Input

1) Number of points
2) Three-Wire availability
3) Linearization capability

e) PID I/O

1) Number of loops available
2) Cascading capability
3) Operator access
4) Software access limits
5) Status data availability and operator display capability
6) Alarms count available
7) Mathematical functions available
8) Dead band
9) Diagnostics availability and capability
10) Update time and rate range

4.1.2.6 Remote I/O

1) Number of remote channels
2) Points per remote channel
3) Limits on I/O mix in remotes
4) Size option (number of modules)
5) Transmission medium to remotes

4.1.2.7 Physical specification

1) Environmental limits
2) Environmental effects on capability of I/O
3) Geographical distribution capability of I/O
4) I/O replacement capability without disturbing the field wiring
5) If special terminals needed for multiwire connections
6) Special connectors for word-oriented (parallel) I/O
7) I/O compatibility with other PLC's

4.1.3 Estimating I/O requirements

4.1.3.1 The following four principal factors shall be considered in defining the I/O requirements for each project application:

- The geography of the plant and the distribution requirement of I/O.
- The I/O types required.
- The number of I/O points required within each different type.
- The extent to which the application requirement has been defined and consequently the spare capacity requirement for future expansion.

4.1.3.2 When the control room is remote from some of the units (i.e., tank farm, utilities, etc.). The PLC chosen shall have remote I/O capability via twisted pair or other type of data link to replace the multiple I/O wiring.

4.1.3.3 When push-buttons, switches, and solenoids are remote from each other geographically, then the location of the remote I/O racks shall be optimally considered for ease of installation and maintenance.

4.1.3.4 For remote I/O estimation, the required number of I/O at each location shall be determined. Comparing this value with vendors' remote I/O capability will determine the number of remote I/O racks required. In stimating the remote I/O rack, the constraint on the I/O mix within a rack, shall also be considered.

4.2 Sizing the I/O Modules

The requirements setforth hereto shall be considered in sizing the I/O system after selection of the Vendor.

4.2.1 In sizing I/O modules, I/O capacity and inputs and outputs mixture limitation within the capacity shall be considered. This final capacity shall be considered in defining the size of PLC for the application.

4.2.2 For I/O module sizing, the ability to use a common side for inputs or the need to provide individual isolated inputs shall be considered on module selection and consequent sizing.

4.2.3 At final stage of sizing and selection, the number of modules required at each location shall be carefully determined, considering all above requirements, to include spare capacities.

4.2.4 In sizing the I/O module, the discrete I/O estimated shall be allocated in raw form and then adjusted for a 20% spare count. Fractions shall be rounded upwards in calculating the number of modules required.

4.2.5 Issues such as; installation convenience, stocking of spare parts and their interchangeability, and the prospects of expansion shall be carefully examined and considered in choosing between 16-bit modules and 32-bit modules and mixture of both irrespective of the initial cost of the modules (unless very large number are involved).

4.2.6 Printer port and programmer port modules shall be considered in parallel I/O rack selection and sizing.

5. CPU SELECTION AND MEMORY SIZING

5.1 CPU Selection

5.1.1 Processor

5.1.1.1 The choice of the processor shall be determined by the magnitude and complexity of the I/O task.

5.1.1.2 The processor specification shall be carefully examined for I/O capacity, the applications program instruction set, memory options, and scan speed, environmental limits and power requirements.

5.1.1.3 The total I/O capacity of the PLC system must be considered very carefully, especially as the application load approaches the upper limit of the PLC. Under these circumstances, a larger model of the vendor PLC system shall be selected.

5.1.2 Processor checklist

The most noticeable items to be evaluated and checked for processor selection are commented herein below. Special block functions which are used in smart I/O modules are not included in this general list.

5.1.2.1 Scan time

Instruction execution times can be used to estimate program scan time.

5.1.2.2 Memory size options.

5.1.2.3 Memory type options.

5.1.2.4 Read Only Memory (ROM) programming method.

5.1.2.5 Memory use: Words per instruction or element.

5.1.2.6 Memory overhead.

5.1.2.7 Memory map, fixed or assignable.

5.1.2.8 Word size.

5.1.2.9 Requester size.

5.1.2.10 Diagnostics: programs shall be checked against the following subjects:

- Start-Up
- Run time
- Diagnostic lights
- Fault indications
- Fault relays available

5.1.2.11 Processor control registers.

5.1.2.12 I/O maximum capacity.

5.1.2.13 Programmer port availability.

5.1.2.14 Communication ports available.

5.1.2.15 Operating modes available:

- Run
- Outputs disabled
- Program/key control availability of the; input/output forcing, requester

5.1.3 Language

5.1.3.1 Ladder diagram language environment can provide many advanced procedures using block functions and data tables which may be considered when the specific application requires.

5.1.3.2 At existing plants where computer already exists or at new projects which DCS will be employed, use of higher level languages may be considered matching with the DCS or computer languages employed.

5.1.3.3 It is highly recommended to select programming tools available on the PLC system. In selecting a programming tool which is not standard supply of the manufacturer, the following features of the program should be considered:

- Fundamental array of programming, editing, and register operations,
- presentation philosophy (menus and key redefinitions),
- inherent provision for documenting program while writing,
- production of records (written, disc, tape, etc.),
- communications capability (can it sit on the network),
- other non-programming uses.

5.2 Memory Sizing and Selection

The next step to be considered comprise of decision about memory size and types.

5.2.1 Memory selection

5.2.1.1 Small PLC (applied for very stable and well-defined tasks) shall use ROM (Read Only Memory) to write the application program instead of RAM (Random Access Memory). Application of such PLC's include; MCC, machinery equipment, packaged equipment, etc.

5.2.1.2 The following option for medium systems may be considered according to the application requirements.

This application of memory system shall use the combination of RAM and EAPROM (Electrically Alterable Programmed Read Only Memory) systems that retain a copy of the program in EAPROM and reload it into RAM on request.

5.2.1.3 Larger systems including plant sequence control system and ESD (Emergency Shut-Down) system shall use battery-backed RAM.

5.2.2 Memory sizing

5.2.2.1 Basically, sizing shall be based on evaluating program needs, allowing some extra memory for scratch pad and future expansion.

5.2.2.2 Basic minimal functional amount of memory shall be carefully examined in sizing the memory considering the requirements in the following paragraphs. Vendors shall be requested to declare this amount of memory in their proposal.

5.2.2.3 In evaluating the memory size of vendors, the basic allotment required by the executive program (operating system) and scratch pad shall be carefully checked for further total memory sizing.

5.2.2.4 Manufacturers may provide crude estimate of memory requirements based on the I/O totals which are only approximate. This estimation shall be carefully exercised, if it is close to the limit of the PLC's memory (which means the system is undersized).

5.2.2.5 For exact sizing, the estimation shall be based on the ladder diagram included in the specifications considering the instruction required for each element. The manufacturers shall be requested to provide information concerning the number of words used in each instruction, to be used for memory size estimation.

5.2.2.6 The estimation obtained in 6.2.2.5 shall be added to the space required by the input and output data tables (with consultation of the manufacturer), considering the memory expansion and the amount of memory requirements as stated in 6.2.2.1, 6.2.2.2. Generally, the internal memory shall be sized such that at least 50% spare memory is available after definition of the I/O tables and entry of the application program.

6. COMMUNICATION SELECTION

The principle Communication system to be selected for a PLC system covers one of the following:

- Network Communication
- Data transfer

6.1 Networking

6.1.1 For PLC system participating in a network with other PLC's, Computers or DCS'S; the selection shall be limited to PLC manufacturers that provide networking scheme. In this regard, MAP compatible systems with open architecture are the preferred choice.

6.1.2 In selecting any other networking scheme, compatibility of the network to the DCS or the computer system shall be carefully examined.

6.2 Data Transfer

6.2.1 For limited communications, such as data transfer between PLC's or for logging alarms, some manufacturers provide parallel ports on their processor which may be selected for specific applications. It should be remembered that in this configuration PLC's are daisy-chained for one-to-one conversations but do not provide full networking.

6.2.2 The common data transfer method to be selected for single PLC system is ASCII I/O module for printer or alarm transfer. The selection shall be carefully made to match the output port parameters with the intended receiving device, e.g., RS 232/RS 422, and software side that includes baud rates, start and stop bits, parity, etc.

6.2.3 For factory floor operations, such as; batch control which need much faster response time and graphic display capability, parallel transmission of backplane bus shall be considered.

6.2.4 For integrating the PLC and other intelligent devices, preference shall be given to Extended Industrial Standard Architecture (EISA) backplane.

7. BATCH CONTROL REQUIREMENTS

7.1 General

7.1.1 Automated batch process control shall be implemented using PLC's suitable for recipe sequence control with improved reporting capability and high level man/machine interfacing.

7.1.2 Batch control shall be applied to all processes which deliver their products as batches. As an example of these processes, the following are outlined hereunder:

- PVC plant
- Continuous catalytic regenerator (CCR)
- Chemical batch reactors
- Batch blending systems
- Manufacturing fine chemicals
- Solid material handling, such as solid catalysers

7.1.3 It should be recognized that, the automation of a batch process control system can shorten batch cycle time by reduction of time delays between process steps and by the deployment of process equipment more efficiently. Such a reduction, which effectively increases the capacity of the capital equipment, can itself justify automating many batch processes.

7.1.4 The automated batch control system design (both hardware and software) shall be in a manner that:

- In case of an emergency arising form process equipment malfunctioning (i.e., failure of a pump, blockage, of a valve orifice) corrective actions performed by software prespecified instructions.

- Where specific actions are not possible or have not been specified, the control system should put the process in a safe state (hold state) before asking the operator to take appropriate action.

7.1.5 Sequence logic functions required for controlling a batch process shall include the necessary steps for responding to abnormal process/plant conditions occurring due to:

- Product problems (e.g., product off-specification or excessive foaming),

- unavailability of plant item or raw material (e.g., common discharge line in use by another reactor, air supply pressure low, or product storage tank full).

7.2 System and Data Base Specification Requirements

7.2.1 For an automated batch control system employing PLC or network of PLC's, a set of application-specific data shall be specified by engineering body in charge of the project. These data shall include all configuration data necessary for setting-up data files of right size (by Vendor), and data required by control system.

7.2.2 Typical data required for Configuring the system which shall be provided for each batch control system, are listed below:

1) Number of units
2) Types of units
3) Number of phases
4) Number of procedures
5) Number of recipes
6) Number of inputs:

- Hardware switches
- Analog alarm limits
- Flags

7) Number of outputs:

- Hardware
- Flags

8) Number of devices employed, per procedure (recipe)
9) Number of timers employed per procedure (recipe)
10) Maximum number of phases per procedure
11) Maximum number of steps per phase
12) Maximum number of contact input per unit
13) Maximum number of contact output per unit
14) Maximum number of devices per unit
15) Maximum number of timers per unit
16) Maximum number of recipe variable per recipe
17) Contact input scan rate(s)
18) Batch cycle time (time between executions of the batch software)
19) Initialization state of contact outputs at the start of the batch for each phase

7.2.3 Unit Data sheets shall be specified for each unit in a system to include the following minimum data:

1) Unit name with identification number,
2) unit type,
3) required number of control consoles (for data entering and monitoring),
4) required number of announciators for alarming,
5) required number of alarm printers.

7.2.4 Input switches data sheets and output switches data sheets shall be specified to include the following data for each input switch:

1) Switch tag number (e.g., PSH-101 A)
2) Switch function description (e.g., reactor pressure alarm)
3) Unit name (unit which this switch is associated)
4) Open state mnemonic (e.g., OK, alarm)
5) Closed state mnemonic
6) Switch type (hardware, analog alarm or flag type)
7) Technical specification

7.2.5 Batch units of the plant shall be defined to match process vessels. Occasionally two or more vessels may be considered as a single unit where vessels operate in conjunction with each other where; it is not practical to separate them in different units. Individual pieces of equipment like pipelines and valves shall be usually associated with pertinent process vessels unless plant's flexibility enhancement requires to keep them as separate units.

7.3 PLC Engineering for Batch Control

7.3.1 In applications where control failure is not tolerable, sufficient back-up system shall be considered for the PLC system.

7.3.2 PLC's applied for batch control system shall have regulatory control (PID) capability.

7.3.3 PLC's for batch control system shall have suitable Man/Machine interfacing with the operating staff and shall provide minimally the following information about plant and process performance:

- Status of each unit or each part of a unit in terms of phase and steps along with the display of alarm conditions.
- Status of individual inputs and outputs and devices displayed in tabular format or with process graphic displays.
- Bar charts displaying the progress of individual batches, occupation of plant times, critical paths, and so on.
- Trend plots of analog and discrete variables.

7.3.4 The interactive displays for operating staff shall include the following functions minimally:

- Facility for the starting of a batch along with assigning of appropriate recipes,
- facilities for putting a batch on hold, shutting down the process, and restarting it,
- acknowledging alarm conditions,
- displaying of sequence logic functions and the facilities for changing them,
- displaying of sequence logic messages and the facility for entering data, when required,
- facility for the manipulation of the states of discrete outputs, devices, and so on, with safeguards to prevent contention problems between operator and control system.

7.3.5 Printers shall be considered for logging alarms and events. The suitable printer shall also be considered to be ultimate backup device for CRT monitors.

7.3.6 For graphic plots such as trend displays, histograms, and so forth, where hard copies are required, pen recorders shall be considered as copying media.

7.3.7 Local operator's stations shall be only considered in areas which need close attention of the operator. It should be noted that; the local displays have little flexibility and does not have graphic display facility. Area classification shall be considered in selecting the local operator station.

APPENDICES

APPENDIX A
SOME USEFUL LADDER DIAGRAM SYMBOLS

Automatically actuated normally open contact
Automatically actuated normally close contact
Normally open manual actuated contact
Normally close manual actuated contact
NO timer contact with delay on energizing (TDOE)
NC timer contact with delay on energizing (TDOE)
NO timer contact with delay on deenergizing (TDODE)
NC timer contact with delay on deenergizing (TDODE)
NO direct-acting limit switch
NC direct-acting limit switch
Normally open held closed limit switch
Normally closed held open limit switch
Foot switch (NO)
Foot Switch (NC)
Relay, timer Coil
Solenoid
Indicator light

A- Amber
B- Blue
G- Green
R- Red
W- White

Horn

PART 2
CONSTRUCTION STANDARD
FOR
PROGRAMMABLE LOGIC CONTROLLERS (PLC)

1. SCOPE

This Standard specifies the minimum requirements for installation, mounting, precommissioning and start-up commissioning of the PLC system used in safety interlock, emergency shut-down and batch control operations in Iranian Petroleum Projects.

It should be noted that, the primary source of information about installation requirements is the PLC manufacturer. The manufacturer will usually provide installation notes for each module type and I/O rack as well as for the CPU/memory.

The information mentioned in this Standard shall be considered throughout the project execution in addition to the manufacturer recommendations and project drawings.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standard and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor.

NEMA (NATIONAL ELECTRONICS MANUFACTURERS ASSOCIATION)

ICS 1-108	"Service and Installation Conditions" 1988
ICS 3-304	"Programmable Controllers" 1988
ICS 1.1	"Safety Guidelines for the Application, Installation and Maintenance of Solid State Control" 1984

NFPA (NATIONAL FIRE PROTECTION ASSOCIATION)

NFC #70	"National Electrical Code" 1987

IPS (IRANIAN PETROLEUM STANDARD)

IPS-C-IN-100/2	"Instrument Installation Procedures"

3. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

4. INSTALLATION AND DIAGNOSTICS

4.1 Installation

4.1.1 Location preparation

4.1.1.1 Consideration shall be given to human factors when deciding the details of the PLC location. The system shall be set at a convenient height for inspection and work on the PLC, and there shall be easy access all around of the PLC equipment.

4.1.1.2 Full advantage shall be taken of existing illumination to provide a well-lighted field of work for the PLC.

4.1.2 Mounting

4.1.2.1 The PLC equipment shall have clear distance from the R.F. or E.M. noise producing equipment, i.e. induction heaters or welding equipment.

4.1.2.2 The following mentioned items provide a checklist which shall be considered in connection with the cabinet location and mounting:

- Easy access to components.
- Clearance and protection of PLC cabinet cooling fan and vent.
- Compliance with electrical standards as indicated in Section 2 herein.
- Suitable electromagnetic shielding.
- Restricting unauthorized access.
- Protection from dust and dirt with provision for adequate cooling.
- Convenient working height of cabinets and consoles.
- Visibility of indicator lights.

4.1.2.3 The following electrical considerations shall be met in executing the wiring of the cabinets and enclosures:

- Providing a well-defined common ground for all cabinets and enclosures.
- Using a common reliable AC source for system and I/O power supplies.
- Segregating auxiliary electromechanical components, such as, starters and relays.
- The wiring shall be at suitable distance, from high energy wiring.
- Each PLC enclosure I/O wiring shall be separated from other cabinets I/O wiring.
- Low level signal wirings shall be separated from all other wiring.
- AC and DC field wiring shall be separated, as much as possible.

4.1.2.4 For mounting and installation of PLC reference, also shall be made to IPS-C-IN-100/2 "Instrument Installation Procedures".

4.1.3 I/O wiring

4.1.3.1 All I/O wires and terminals shall be clearly labeled.

4.1.3.2 The input devices shall be wired, so that they switch the hot side of the line. A similar method shall be used for the PLC outputs.

4.1.3.3 For inductive load outputs, a capacitor across the secondary side of the disconnect switch supplying power to the inductive load shall be provided for outrush problem.

4.1.3.4 Acceptable wiring practice must be followed for all I/O’s of the PLC.

4.1.3.5 Special consideration must be given to execution of analog I/O low-level signal sources such as thermocouples.

4.1.3.6 Where, a voltage divider is used to match a field transmitter voltage range to that of the PLC's A/D, the resistances shall be chosen so as to use as much current from the field device as is permissible, in order to provide the maximum signal-to-noise ratio at the input.

4.1.3.7 The wirings shall be run in the shortest possible routes.

4.1.3.8 Joining the cables for increasing the cable length shall be avoided.

4.1.3.9 Cabling along vibrating supports or sources shall be avoided.

4.1.3.10 Minimum 10 cm radius shall be used on cable bends for two core cables.

4.1.3.11 Different voltage and types of signals shall be separated, as much as possible.

4.1.3.12 In order to avoid ground loop problems, the shields on shielded cables must be grounded at one end only. This ground can be conveniently established at the cabinet end of the cable.

4.1.3.13 As each module wiring is completed, check of the wirings shall be performed for mechanical strength by pulling at each connection and verifying the labeling.

4.2 Precommissioning

There are several phases of precommissioning check-outs that must precede any start-up of the system, namely:

a) Component inspection
b) Clearing resetting the PLC
c) Input wiring check
d) Output wiring check
e) Program check
f) Power check
g) Loop check

All of the above checks shall be performed by the contractor and witnessed by the Company's inspectors. A checklist form shall be prepared by the contractor to indicate all requirements of this Standard. Inspector, contractor, and the Company's representative shall sign the forms when the checklists are completed. The Vendor representative shall be present for the tests involving the PLC operation, when specified in pertaining procurement.

4.2.1 Component inspection

4.2.1.1 This inspection shall be performed to ensure that all components of the PLC are present, are correct as to model and type, and are correctly installed in the correct location.

4.2.1.2 CPU/memory unit and the I/O shall be inspected. Correct models of the modules shall be established and adequate addresses shall be checked. If addresses on the I/O rack are created by thumb wheel switch settings on the rack unit then the settings shall be verified for the correct range. The mechanical condition of the modules and wiring shall be checked to ensure that all units are firmly seated and all terminal screws are secured.

4.2.1.3 Wire labels and module types and addresses shall be checked using the PLC's I/O list document.

4.2.1.4 Cables to the remote I/O shall be checked to verify that they are connected to the correct remote terminals.

4.2.1.5 Polarity of power supply connections shall be checked to be correct.

4.2.1.6 Wiring at the field end shall be inspected to establish wire identity and verify that safety precautions have been taken to avoid damage when input devices are actuated during check-out.

4.2.1.7 Output wiring at the field end shall be inspected to establish the wire identity and to verify that the outputs are safe to test.

4.2.2 Clearing (resetting) the PLC

4.2.2.1 PLC application memory shall be blanked to avoid unexpected behavior from residuals. This should be done with the system in the "disable output" mode, if available.

4.2.2.2 Before clearing (resetting) the PLC, it should be made sure that documentation for the diagnostics is at hand and is the correct revision for the particular PLC model involved.

4.2.2.3 Documentation for CPU run and shutdown procedure shall be checked to be clearly established and documented.

4.2.3 Checking the inputs

4.2.3.1 This check requires that the programming tool and the CPU/memory are both in functioning condition. It is intended to establish that the input wiring is correct, that the input addressing scheme is correct, and that the input field devices and PLC modules function correctly.

4.2.3.2 Before starting, the consequences of manually operating the field devices should be considered and appropriate safety precautions shall be checked, as follows:

1) The PLC shall be set in a nonscanning mode so as to inhibit any action other than shutdown. Then power shall be applied to the system and input devices.

2) Correct function shall be checked by examining the relevant indicator lights on the processor, power supply, and I/O units. All remote I/O's shall also be checked, accordingly. It shall be verified that, in case of shut-down of any output, the power is removed from the pertinent output device.

3) The programming device shall be connected to the PLC to monitor input status. Each field device shall be actuated manually, and the input status light on the input module and status of the input in the input address register in the memory shall be observed.

- If the wrong module indicates the field changes then the wiring shall be corrected.
- If nothing happens, the fault lies either with the input module, the wiring, or the field device, assuming that all power is correctly applied and that the safety precautions did not accidentally inhibit the action of the field device.
- If the changing input status shown by the module light is not reflected by the status display of the programming device, the address may be incorrect, the module may be defective. CPU problem is unlikely during this check since the system perform an internal check upon power-up and will display a diagnostic light.

4.2.4 Checking the outputs

4.2.4.1 Power shall be applied to the PLC's processor (with the field device under test disconnected locally) for output tests. Generally, the output check is similar in form and function to the input check.

4.2.4.2 The processor shall be started in the output disabled mode and power shall be applied to the I/O's. The emergency power-break for the output shall be checked, while all diagnostic lights display are verified to be correct.

4.2.4.3 Each output shall be checked by energizing and observing the module indicator light. It should be noted that; problems here are usually the consequence of addressing problems. Energizing of the output shall be accomplished by using the forcing function of the programming device or by programming a single rung with a convenient local switch as input and a coil with the appropriate address for the output under test. In the latter case, pressing the switch with the processor in the scan mode will provide the test required.

4.2.4.4 The output wiring shall be checked by reconnecting each field device as it is to be tested.

4.2.5 Program check

4.2.5.1 The control program shall be carefully reviewed before it is loaded into the controller for start-up. The review must include all documentation, including any changes to the I/O list or address revisions that occurred during the I/O check. It should be noted that; the program to be loaded may differ slightly from the actual program final form because it contains special rungs for the start-up procedure. Both actual and loading programs must be reviewed.

4.2.5.2 The program review may take place at any time after the initial I/O checks but must precede the start-up.

4.2.5.3 When start-up is initiated, the program as loaded must be compared with the documented copy used for the review. Specially, the output device addresses must be confirmed to be in agreement with the program rung addresses as loaded, as well as making checks for generally valid contact and internal coil addresses.

4.2.5.4 All preset data shall also be checked, e.g., counter and timer loads, time bases, and similar reference data.

4.2.5.5 After the program has been loaded into the PLC and checked, a copy of "AS-BUILT" program listing shall be generated by the processor.

4.3 Start-Up (Commissioning)

The principal requirement for start-up is the establishment of an orderly and documented sequence of events. Depending on the PLC manufacturer, there may be detailed procedures provided in the product manuals. The walk-through can be recommended as an evaluation technique, especially if the review group includes engineers who are familiar with the process but have not been deeply involved in the PLC implementation.

Some recommendations are presented below, but procedural details will be highly specific to the particular application. Sometimes special start-up programs are used for a preliminary test of the system and components before initiating the full control:

1) After loading and checking, a preliminary start-up is usual, with outputs disabled to permit preliminary debugging. If the system is large, a segmented start often simplifies matters. The remote I/O that is usually present in such systems can be disabled by disconnecting the communications cable, removing power, using temporary MCR’s, or register fencing, as is appropriate.

2) The I/O can be enabled with the field devices connected up in sequence, either singly or in groups, depending on the system complexity. Each should be observed for correct action. In some applications, the ability to record the sequence of events using the programming tool may provide considerable assistance.

When the system is operating correctly and at as many intermediate points as is practical, the program in use should be recorded and stored on a loadable medium, such as magnetic tape, and on paper for human use.

4.4 Diagnostics

4.4.1 General

PLC manufacturer’s provided diagnostic aid will be performed on applying power to the system and concluded by the display of an indicator light on the processor. During this check, the executive RAM and ROM will be tested along with, some other main functions. Any serious failure at this level will cause a fault relay to open, shutting down system power. Less serious problems are usually flagged by an indicator light; the particular problem is then referenced in an error table register. If the system is functioning correctly and the user starts loading a program, there may be two error listings available: one for indication of programming errors, and a second list stored under the label of " processor errors".

Diagnostics, discussed hereunder are; user-called set of diagnostics, initiated by some of programming device optional programs.

4.4.2 Requirements

4.4.2.1 User-Called set of diagnostics shall be called via programming device to check all memory, all interrupts (both internal and programmable), and all communication parts. Failures will be classified by their severity as fatal or nonfatal at this stage. Before initiating the system check, assurance shall be made at this point, that no fatal or nonfatal errors are present.

4.4.2.2 The following operations shall be checked by means of program options provided on the programming device:

1) The display of the ladder program with each coil and contact represented together with its current logic state.

2) The ability to perform time scan operations in which a particular program event can be scheduled as a trigger. This trigger then starts a procedure that records the subsequent order of events, such as input, output, or program induced logic changes, and provide the timing details for the recorded sequences.

The display of any other program present on the system with correct logic state indication.

4.4.2.3 The contents of certain control registers normally used by the CPU and the executive program shall be examined for diagnostic purpose.

4.4.2.4 Similar registers, as 4.4.2.3, but used by intelligent I/O modules shall be inspected.

5. SITE ACCEPTANCE TEST

5.1 General

Test shall involve both process equipment and the control system. The site acceptance test is functional test and may be carried out in stages with procedures similar to the Factory Acceptance Test, but, with the actual process input and outputs connected.

In batch control system, the process shall usually be run dry or with some inert material for one or more batches.

Testing of sequence logic for a multisequence or multiproduct batch plant shall normally be done with one test recipe, or at least a small number, designed to exercise all logic paths. Anyhow, the batch control system shall be separately exercised to run each unique recipe before the recipe is released for normal production.

Upon completion of the installation and pre-commissioning checks of Section 4 heretofore, the Site Acceptance Test (SAT) shall be performed. The SAT will be witnessed and signed off by Vendor, Contractor and Company.

5.2 Test Environment

Proper environment shall be prepared for in-process and Site Acceptance Test as outlined hereinafter.

5.2.1 Simulation

5.2.1.1 Both hardware and software shall be prepared to establish an environment equivalent to that encountered in actual use, enabling to find out the greatest member of problems prior to system's placement into service.

5.2.1.2 Simple simulator may be built by; contact inputs and outputs wired to switches and indicators lamps, respectively, to observe the indicator lamps and change switch states accordingly.

5.2.1.3 For timing check, the output-to-input connection may be made through a time-delay relay with delay adjustable over the range of interest. This tests shall be performed to simulate the process plant response, where plant response is critical in logic operations.

5.2.1.4 A simple input-to-output connection, provided that the electrical requirements of both input and output circuits are met, may be employed to simulate a process plant response.

5.2.1.5 High-speed pulse train inputs, typical of the outputs of several types of flow transmitters, may be generated by square-wave generator. Connections shall be made carefully in light of varying electrical requirements found among different input circuits. The pulse generator may be set to generate an output similar to, or faster than, that expected from the plant to speed up testing.

5.2.1.6 Testing of analog loops shall be performed with laboratory-type process simulators or dynamic, lag simulator units.

5.2.1.7 Software simulation shall not be used for the purpose of testing in SAT.

5.2.2 Utilities

5.2.2.1 Software utilities shall be used to enhance the test by providing visibility and access for manipulation of the control system under test.

5.2.2.2 For SAT, the PLC's Vendor shall be requested to provide the following utility programs, for control systems, as required:

- A routine to "dump" the current contents of recipes, unit variables, status bits, I/O files, and so on, to the CRT screen or hard copy for batch control system.

- A subroutine or routine to observe and manipulate data flow among software modules, including between process units with ability to trend these signals on one CRT screen.

- A program in the programming device to force both discrete and analog I/O.

- A program for testing the printer performance.

5.2.2.3 All vendor provide utility programs, as indicated in operating and maintenance manuals shall optimally be used to verify the operatability of PLC system.

6. DOCUMENTATION

At satisfactory completion of the Site Acceptance Test, a final certificate of acceptance shall be prepared by the Vendor/Contractor. Attached to the acceptance test documents shall be all test records, receipt for PLC's documentation and spare parts plus any other pertinent record regarding the Vendor's/Contractor delivery. These document will become part of certificate of Final Site Acceptance which the Company representative will review for final acceptance certificate issuance.