MATERIALS AND EQUIPMENT STANDARD

FOR

DISTRIBUTED CONTROL SYSTEM (DCS)

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1. SCOPE

This Standard specification defines the minimum requirements for functions, hardware, and firmware/software of DCS employed in Iranian Petroleum Industries projects. The detailed requirements will be specified for each individual project as a supplement to this Standard specification.

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.

BS (BRITISH STANDARD INSTITUTION)

BS 5760	"Reliability of Constructed or Manufactured Products, Systems, Equipment and Components" Part 5

ANSI (AMERICAN NATIONAL STANDARD INSTITUTE)

ANSI/HFS-100	"Human Factors Engineering of Visual Display Terminal Workstations" (1988)

IEC (INTERNATIONAL ELECTRO-TECHNICAL COMMISSION)

516	"A Modular Instrumentation System"
625-1	"An Interface System for Programmable Measuring Instruments: Part 1 & 2 (Byte Serial, Bit Parallel)"
68/2	"Basic Environmental Testing Procedures for Electronic Components and Electronic Equipment"
297	"Dimensions of Panels and Racks (for Nuclear Electronic Instruments)"
482	"Dimensions of Electronic Instrument Modules (for Nuclear Electronic Instruments)"

EIA (ELECTRONICS INDUSTRIES ASSOCIATION)

RS 232C	"Interface Between Data Terminal Equipment (DTE) and Data Communication Equipment Employing Serial Binary Data Interchange (25 Pin Connector)"
RS 310-C	"Racks, Panels and Associated Equipment" 1972-(R1983)
RS 422	"Electrical Characteristics of Balanced Voltage Digital Interface Circuits"
RS 423	"General Purpose 37-Position and 9-Position Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange"
RS 449	"Physical Characteristics of the Connectors for RS-422A Interface Circuits"

IEEE (INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS)

C 62	"Guides and Standards for Surge Protection" (Complete 1990 Edition)
488	"Standard Digital Interface for Programmable Instrumentation"

802.3	"Carrier Sense Multiple Access (CSMA) with Collision Detection Access Method and Physical Layer Specification"
802.4	"Bus Oriented Token Passing Network"
802.5	"Token Passing Network Using a Physical Ring on Twisted Pair Wire or Cable"

ISA (INSTRUMENT SOCIETY OF AMERICA)

S 18.1	"Annunciator Sequence and Specification"
RP 55.1	"Hardware Testing of Digital Process Computers" = ANSI MC 8.1
S 61.1	"Industrial Computer System FORTRAN"
S 61.2	"Industrial Computer System FORTRAN Procedure for File Access and Control of File Contention"
S 72.01	"PROWAY-LAN Industrial Data Highway"

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

7498-1	"Information Processing Systems-Open System Interconnection (OSI)-Basic Reference Model" (1984)
8348	"Data Communications-Network Service Definition" (1988)
8473	"Data Communications-Protocol for Providing the Connectionless-Mode Network Services" (1989)
8802/2	"Logical Link Control" (1990)
8802/4	"Token-Passing Bus Access Method and Physical Layer Specifications" (1990)
8072/8073	"OSI-Connection Oriented Transport Protocol Specification" (1988)

NEMA (NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION)

ICS6	"Enclosures for Industrial Control and Systems" (1978)

MIL-STD (U.S. MILITARY STANDARD)

MIL-STD-HDBK-217	"Reliability Stress and Failure Rate Data for Electronic Equipment"
MIL-STD-1629A	"Procedures for Performing a Failure Mode Effects and Criticality Analysis"

3. UNITS

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

4. SYSTEM REQUIREMENT

4.1 General

4.1.1 The DCS shall be totally distributed digital process control and data acquisition system with shared display. The DCS shall preferably be of "open system type" according to ISO 7498-1.

4.1.2 The DCS shall be furnished with a unified data-base enabling implementation of all types of control strategies. Basic system shall be made of four building block subsystems naming communication system, general purpose controllers, process interface & data acquisition system and operator interface. The system shall be configured in hierarchial architecture to be capable to be integrated into higher automation levels as illustrated in Appendix A.

4.2 System Architecture

The Distributed Control System shall provide both geographical and functional distribution by means of highly optimised modular architecture for simple, cost effective future expansions. The following levels shall be incorporated into the DCS architecture.

4.2.1 Process control level (level 1)

This level shall cover all microprocessor based controller files, input/output connection terminals, A/D and D/A converters, and signal conditioning circuits. Each module in distributed architecture shall include a microprocessor with it's own firmware and data-base. Each building block module shall be task partitioned and shall be tailored to perform a specific dedicated task, such as; process interface, control strategy implementation, data highway interface, etc. Each task shall be performed in each block independently of other blocks.

Interconnection between controllers and shared display shall be implemented by means of a data highway which shall be a part of basic system's communication network.

4.2.2 Process supervision level (level 2)

The next level above the process control level just described is process supervision level. At this level, operator interface to the process and to the higher levels will be performed.

4.3 System Configuration

4.3.1 The DCS system shall be comprised of a family of hardware and software to implement all types of process control systems. The system shall provide a distributed intelligence architecture with shared display, in a manner to combine; operator interfaces, process controllers and input/output modules into an operating integrated system effective at the loop, unit and plant control levels.

4.3.2 DCS modules shall be integrated together through a data bus oriented communication link system. Alternatively, communication link employing IEEE 802.3 and/or IEEE 802.4 standards may be proposed.

4.3.3 The system configuration shall basically comprise of the following building block sub-systems :

- Communication system
- General purpose controllers
- Process interface and data acquisition system
- Man-Machine Interface (MMI)
- Data highway ports for interfacing with PLC'S & Batch sequence control
- Data highway interface to higher level automation computer systems.

4.3.4 The system shall be structured so that a physical separation between the safety oriented functions and process control related functions can be easily achieved.

4.3.5 The system shall be sized to contain 40% spare I/O capacity, 20% of them installed in the system, unless otherwise specified. The system shall maintain the same real-time system response, and shall maintain an adequate traffic load within communication network after full expansion.

4.4 System Security

4.4.1 General

The security of the instrumentation system shall be confirmed by all precautions necessary to ensure that the control will continue uninterrupted, in case of equipment breakdown.

These precautions shall include minimally back-up redundant modules, manual mode on controllers that allow manual operation, should the normal operating modes (i.e. computer, cascade, automatic) be unavailable. The following security procedures are mentioned, as a minimum, preference will be granted to systems with more reliable security measures.

4.4.2 System design

4.4.2.1 The system design shall be based on highly modular components at all levels using the state of the art technology.

4.4.2.2 The following points shall be considered in the system design by hardware and software/firmware configurations:

- Function distribution shall be used to minimize the consequences in the event of a failure occurrence in the system and to simplify maintenance.

- The system display shall be divided in hierarchial pages, with each level of the hierarchy providing more detail information about a specific item or area in a manner that the following levels to be available for the operation of the process.

Level 1: Overview display of overall plant status with arriving alarm annunciation.
Level 2: Plant process area overview with arriving alarm indication.
Level 3: Portions of the process area (depending on the size of process area), with arriving alarm indication.
Level 4: Equipment overall display (group display) with alarm indication.
Level 5: Single loop or point detail display showing process value, set-point, tuning parameters and all information about the loop.

4.4.2.3 The system shall also provide a dynamic display hierarchy based on alarm priorities to ease quick access to the highest priority alarm for the process area involved.

4.4.3 Reliability

4.4.3.1 The reliability for DCS shall establish measuring guidelines to determine compliance with requirements set forward in this standard specification and shall indicate risk as well as need for redundancy, fail-safe design, spare part stocking, and any other protective measures available. Details of definition and equations are included in Appendix B.

4.4.3.2 Software reliability aspects of the system should be discussed and approved by Company.

4.4.3.3 The equations indicated in Appendix B shall be used by the DCS vendor to perform detail calculations report of his proposed system Availability and shall be submitted by his bid proposal to the Company.

4.4.3.4 The reliability report, in addition to the Availability result, shall contain the following:

- The study boundary
- The assumptions
- The Availability block diagram
- A summary of the techniques or Computer software employed
- A data table listing all equipment failure rates (or probabilities of failure) and restoration times with reference to the data source.

4.4.4 Failure recovery requirement

The system shall be fault tolerant to achieve the availability measures mentioned herein and the system shall utilize the following failure recovery measures to exceed 99.9% availability minimally.

4.4.4.1 Redundancy

-Uninterrupted automatic operation desired in the system, shall be achieved by suitable redundant devices, such as; power supplies, controllers, displays, communication system, sequence and interlock system. In order to take full advantage of a redundant system, it must be possible to repair a fault in the redundant parts while the others are kept on-line.

4.4.4.2 Manual over-ride

The operator will be considered as ultimate back-up for the control of the process, but such a measure shall not be considered in availability estimation stated here-to-fore. Such a capability shall fulfill the following requirements:

- Manual over-ride shall be made available for all process outputs.

- Manual over-ride shall be available through a hierarchy of redundant and supplementary independent paths to ensure prompt action to be taken as required. Various operator interfaces shall be connectable and removable to the system without affecting other stations or disturbing other control actions.

- Sufficient quantity of separate portable or local manual control/display stations shall be provided for the system to be used for various modules of the system. These devices will be used as stand-by devices to program and/or operate controller modules independently of the communication system, if specified.

4.4.4.3 Maintainability

- The modules of the DCS shall be designed, in a manner to be replaced without hampering regular operations.

- Repair policy shall be based on replacing PC boards from a small quantity of recommended spare boards. The vendor shall have the capability to provide complete After-Sales-Services for repairing the cards and to provide enough spare PC cards for ten years, minimally.

4.4.4.4 Automatic self-diagnostics

- The distributed control system shall continuously monitor itself for failure of it's components (modules, processors, buses, etc.) and shall provide prompt advice to the operator when a failure is detected, by means of, automatic self-diagnostics program. All devices operating within the DCS shall be under continuous surveillance by self-diagnostic programs.

- Upon any malfunctioning, a designated back-up device shall be switched into operation automatically.

- System overloads such as memory capacity, scan rate etc., shall be alarmed at the operator console. The status of failed module(s) shall be made available as a hard copy print-out.

- The system shall be equipped with suitable diagnostic software and hardware to locate and identify faults and malfunctions with details such as; time of failure occurrence, identities of faulty devices, major components malfunctioning and the back-up system which are activated automatically.

4.4.4.5 Off-Line diagnostic programs

System shall be provided with off-line diagnostic programs to perform a through detailed check of the equipment. The Vendor shall submit detailed description of his off-line diagnostic programs with his proposal to be evaluated by the Company. Diagnostic program shall be capable to perform integrity checks to determine if a hardware or software error has occurred in the system.

4.5 System Continuity

The system shall have continuity of design and updating, that is; the system shall be capable to accept all new developments and updating of the system without any need to obsolete the existing system in favor of the new one.

4.6 Alarm Handling

4.6.1* Alarm annunciation shall not cease without acknowledgment when points return to normal.

4.6.2* Audible annunciation is not required when points return to normal.

4.6.3* The Alarm Silence Key shall immediately silence the audible annunciation of any alarm.

Note*:

For more details reference may be made to ISA S18.1.

4.6.4 Acknowledgment of any alarm shall be inhibited until sufficient detail is presented on the display to identify the nature of the problem to the Operator (e.g. Detail Display or Group Display including the annunciating alarm points).

4.6.5 A means of quickly and easily guiding the Operator to displays of annunciating points must be provided. This could be a list of displays with unacknowledged alarms or a key for directly accessing the appropriate displays.

4.6.6 A quick and easy mean for inhibiting and restoring all configured annunciation capabilities of any Operator Station at a time must be provided. Access must be restricted to authorized Engineering Personnel only. This requirement will allow same configuration to be used for all Operator Stations while permitting authorized Engineering personnel to randomly select the Operator console to be used for alarm annunciation.

4.6.7 The system shall support the following features:

- Minimum of 4 alarm priority levels
- Configurable event logging on printer with the following information, as a minimum
- Tag number, description, timestamp, and reset time.

5. SYSTEM HARDWARE REQUIREMENTS

The hardware configuration shall be divided in the following sub-systems:

- Communication system
- Controllers
- Process interface units and data acquisition
- Man-Machine-Inerface (MMI)

The hardware units shall be manufacturer standard as "Off the Shelf" items.

5.1 Communication System

5.1.1 General

Communication links of the DCS shall basically conform to Manufacturer Automation Protocol (MAP). Preference will be given to International Organization for Standardization (ISO), Open System Interface (OSI) data communication concept as outlined in Section 2 here-to-fore.

5.1.2 Communication medium (physical network)

The communication media shall consist of fully redundant cable trunk running plant-wide to transfer data between different process controllers and shared display operator stations. Connection between components shall be made by means of flexible drop cables branched off the main cable.

5.1.2.1 The trunk cable may be made of semi-rigid, coaxial or fiber optic cables, as required.

5.1.2.2 The shields of all trunk and drop cables shall provide an effective shielding factor of 100%.

5.1.2.3 Redundant trunk bus media shall be provided for the DCS. These redundant media shall function correctly for all DCS data communication demands independent of the main trunk.

5.1.2.4 Separate connectors shall be provided for jabber-inhibit monitoring for each communication medium. Received signal source selection circuit shall be capable of selecting any one of the redundant media automatically and it shall be possible to enable or disable each single transmitter independently of the other redundant transmitter when the source of received signal is one of the redundant media.

5.1.2.5 The physical layer design entity shall be, such that; the probability of a communication error, causing malfunction of other controllers connected to the medium to be less than 10^{-6} (bit error rate).

5.1.2.6 The link media shall provide total electrical isolation between plant areas, to minimize the ground loop problems.

5.1.2.7 The media shall not be prone to problems arising due to moisture and corrosion.

5.1.2.8 Provision shall be made for the redundant link medium to operate normally without upsetting overall operation or requiring any modifications in the link, in case that; any number of connected modules fail or for removing and replacing any connected device.

5.1.2.9 The communication link shall be capable to service in hazardous area classified environment.

5.1.2.10 The communication interface cards in each sub-system shall be galvanically isolated from the Bus.

5.1.2.11 The communication interface card shall also be provided with a hardware timer which disables communication, if transmission time exceeds abnormal values.

5.1.2.12 Bus control shall preferably be performed by token passing or CSMA/CD method in accordance with one of the following standards:

IEEE 802.3
IEEE 802.4
IEEE 802.5
ISA/S 72.01

5.1.2.13 The access cycle time to the Bus will be dependent on communication load and the number of system equipment connected to the Bus, but anyhow in all circumstances, this access time shall not be greater than 500 m Sec.

5.1.2.14 All communication failure shall be reported suitably to the operator station. Such failures shall be logged in the system's diagnostics list. Continuous communication routine shall detect the communication system failure for alarming and switching to the redundant medium automatically.

5.1.2.15 Request for internal DCS information exchanges shall be generated from one of the following sources:

- Real time clock
- System error detection procedures
- Status changes
- Or any combination of these sources.

5.1.2.16 In periods with high communication load, the system shall consider priority for alarm transmissions over system information request.

5.1.2.17 The data protocol used shall safeguard against false data transmission and shall detect transmitted data errors.

5.1.3 Multiple data highways

5.1.3.1 Necessary interfaces shall be provided in the system to link 16 data highways in Bus, Ring or Star architecture or any combination of them, as a minimum.

5.1.3.2 Routing of data among multiple highways shall be handled, in a manner that; error detection on one communication path results an intelligent re-routing along other possible communication paths.

5.1.3.3 Multiple highways shall preferably work on the basis of IEEE 802.4 or IEEE 802.5 (ISO 8802.4 and ISO 8802.5 respectively) standard.

5.2 Controllers

The system shall perform the conventional control strategies by dedicated microprocessor based digital controllers capable of being installed in control building or field auxiliary rooms. The following points shall be fully met as a minimum:

5.2.1 The controller shall be micro-processor based digital type using at least 16 bit industrial type microprocessor to provide multifunction process control.

5.2.2 Scaling, filtering, conversion to engineering units and alarm checking of analog measurement values shall also be included through standard predefined functional blocks.

5.2.3 Special function blocks shall be made available for floating point calculations. All control calculations and reporting shall preferably be performed by floating point arithmetic to avoid scaling problems. Measured values, as well as, calculated variables shall be accessible to these calculation function blocks.

5.2.4 Executive routines and control logic shall be stored, by suitable Read Only Memory (ROM), in a manner that; setting values and tuning constants are not lost or altered if the module fails or when a power surge or power interruption occurs.

5.2.5 Control routines shall permit on-line changes to be made in any parameter of the controller, including reassignment of input or output signals. This task shall not affect the operation of other loops implemented in the same microprocessor and shall not create any plant control upsets.

5.2.6 Output and set-point tracking shall be automatic and shall be available for all types of controllers for bumpless transfer of mode changes.

5.2.7 Each controller module shall have a dedicated data-base, containing information on the performance of the device and the status and history of the process variable in non-volatile memory for protection against power outages.

5.2.8 Control modules shall function autonomously, in a manner that, failure of one of them does not take others out of service.

5.2.9 Controller set-points and output ramping speeds shall be adjustable through operator console or portable maintenance terminal.

5.2.10 Controllers shall be equipped with the following modes of operation minimally, selectable from the operator console:

a) Manual

- The output will be manipulated directly from the operator station.

b) Automatic

- The output will be computed by the DCS controller.

c) External/Internal set-point (Cascade)

- The set-point will be the output from another controller or the same controller loaded with another control algorithm. Bumpless transfer between different modes shall be provided in the controllers.

5.2.11 Autodiagnostics shall be run in the controllers to detect sensor faults (bad PV) or operations out of tolerances, as well as, failure of component blocks, such as:

- A/D and D/A converters
- Memories
- Power regulators
- Communication system interfaces
- Central Processing Unit (CPU)

5.2.12 When the above mentioned problems identified by the autodiagnostic routines, the system shall place the affected loops in a safe state to prevent any incorrect final element positioning. The detected error shall trigger appropriate alarms, diagnostics codes, and status displays at control centre, and pertinent PC card(s).

5.2.13 In the event of entire controller failure, the system shall reassign the contained loops to the back up controllers or to the operator station, automatically. The latest valid command shall be held during switch-over to avoid process upsets.

5.2.14 Controller parameters shall be checked to prevent entering of unreasonable values by the operator and to detect erratic signals obtained from other loops. The checked parameters, in addition to, the set-points, shall include:

- Any parameters which affect tuning or control strategies
- Parameters establishing alarms
- Output limits

5.2.15 During the program modifications, all process outputs shall be placed on hold and parameters shall be checked with unreasonable entries alarmed.

5.2.16 Each controller block within a controller card shall be capable to accept customer selected equations or algorithms, without affecting other loops via operator console.

5.2.17 The controller including the back-up shall have a real-time database to perform actual control and monitoring functions. The data stored in this database shall be, minimally, as follows:

- Operating parameters, such as; the current process value, set-point, valve output, and mode (automatic or manual)

- Tuning parameters including values, such as gain, reset, derivative, and alarm trip-points.

5.2.18 The variety of controller card to perform all control functions shall be limited types to ease the maintenance and spare parts stocking of the system. The vendor shall furnish detail technical document for his proposed controllers to be evaluated by purchaser.

5.2.19 Controller configuration data shall reside in non-volatile memory media.

5.2.20 Special indicators shall be incorporated in the design of printed circuit boards to ensure rapid detection of malfunctions and current status by maintenance personnel to be used for isolation of failures and performing the repairs. These indicators may be Light-Emitting-Diodes (LED) on the circuit cards to reduce the need for test equipment.

5.2.21 Controllers shall be capable of being replaced while the system is powered up without requiring any other controller in the system to be shut-down.

5.2.22 On-Line control configuring capability shall be considered for the controllers,with no need to take them off-lin.

5.2.23 The controllers shall be capable to be operated durably in wide ranges of; temperature, humidity, dust, atmospheric corrosion, and contamination, if requested.

5.3 Process Interface and Data Acquisition System

5.3.1 General

The DCS shall provide a comprehensive set of I/O conversions to interface with all types of standard analog and digital input/output signals encountered in the process. The requirements for this kind of interface will be specified under "process interface modules".

In addition to process interface modules, a "data acquisition system" shall be furnished with serial data communication to DCS-BUS, to achieve a truly integrated process control system with all packaged unit instrumentations in the plant, if specified.

5.3.2 Process interface modules

5.3.2.1 The process interface modules shall be capable of interfacing with the following types of input signals from field sensors and transmitters.

a) 4-20 mA from transmitters.

b) 1-5 Volt from different electronic sensors

c) Millivoltage with cold-junction temperature compensation for thermocouples.

d) Resistance measurements from RTD sensors

e) Pulse inputs from turbine-meters, rotational speed measurements, etc. in the range of 0-1 or 0-10 Volts at frequency range of 1-2000 Hz.

f) Floating dry contacts, with 120 V ac, 110 V dc or 24 V dc power supply by a source external to the process interface.

g) BCD signals from inductive position sensors.

h) Direct digital signal from smart transmitters.

5.3.2.2 The input cards shall be solid state electronics employing the state of the art technology.

5.3.2.3 Digital input/output cards shall have LED On/Off status indication for all inputs/outputs.

5.3.2.4 Any input or output card shall be replaceable without turning-off the power to the system or disturbing the operation of the rest of the system, in any way.

5.3.2.5 Light Emitting Diodes (LED) shall be provided in process interface cards for indication of errors occurring within the unit and for confirmation of correct operation of the system.

5.3.2.6 The input/output cards shall perform all necessary conversions, such as; A/D, D/A, code conversion, filtering, etc. required to perform interfacing to the process.

5.3.2.7 The process interface card electronics shall convert all low level input signals to standard 1 to 5 volts and apply any necessary conditioning, such as:

- Square root extracting
- Thermocouple cold junction compensation
- Noise suppression filtering
- Linearization for non-linear signals
- Open or grounded thermocouple detection

5.3.2.8 The vendor shall quote conversion repeatability and accuracy of A/D and D/A in his proposal to be evaluated for each specific application. The sampling rate shall be suitable for scaning time of 100 msec. for each individual control loop.

5.3.2.9 The input/output circuitry shall be provided with suitable over-voltage protection.

5.3.2.10 The I/O system shall supply the operating power to the field instruments connected to DCS via power supply units installed in the same cabinet.

5.3.2.11 The I/O system shall provide required electrical isolation, noise rejection, transient suppression, to ensure clean, accurate information to the controllers for monitoring and control. Signal conditioning, isolation, and surge protection for analog and discrete I/O shall be preferably performed by signal conditioning modules mounted on the termination panels.

5.3.2.12 The I/O system cabinets shall contain high quality terminals to allow easy installation of field wiring and labeling of terminations.

5.3.2.13 The I/O system shall be capable to be operated durably in wide ranges of temperature, humidity, dust, atmospheric corrosion, and contaminants which are present in typical oil industry installation. The specific environmental condition will be specified for each project.

5.3.2.14 In hazardous locations where isolation or energy limitation to field devices are essential, the I/O system shall be capable to be equipped with safety barriers inside the termination cabinet.

5.3.2.15 The I/O system termination panels shall be separated from the I/O electronics to provide enough space for ease of wiring installation. The termination panel shall be located at the sides of the cabinets.

5.3.2.16 Redundant I/O system shall be provided for critical loops using the back-up I/O to keep the process running, if the primary one is damaged or malfunctioning, unless otherwise specified.

5.3.2.17 Fuses and relays of the I/O card shall be readily accessible and can be changed without disrupting service of any other channels.

5.3.2.18 All non-intrinsically safe circurits shall be provided with suitable fuse protection in the termination block.

5.3.2.19 The I/O system shall be equipped with multiple channel signal conditioning cards to perform scanning, filtering, and alarm implementation on all field instrument analog measurements for each group of I/O cards.

The card shall provide the following features on per channel basis:

- Selectable signal conditioning
- First or second order filtering
- High/Low limit absolute alarming
- Bad or faulty input alarming

5.3.2.20 The overall accuracy of I/O system shall be 0.2% F.S. minimally subject to the following conditions:

- The output signal reconstructed from the digitally stored data.

- The stated accuracy shall apply individually to each input/output pair with the system operating at a data rate up to the maximum rate for all I/O channels.

5.3.2.21 Any electronic components located on the I/O system modules shall be capable of operation with the specified performance during repeated shock loading of 1.0 g trapezoidal pulse of 30 m Sec. duration.

5.3.2.22 The data cable and cable attached connectors shall be capable of surviving at a repeated shock loading of 7.0 g trapezoidal pulse of 30 m Sec. duration.

5.3.2.23 I/O system component modules located on test sled shall be capable of operation within the specified performance during exposure to sinusoidal vibration of 2.5 mm. peak-to-peak at frequencies from 10 to 60 Hz., with 0.5 g maximum acceleration.

5.3.2.24 All calibration parameters of the I/O cards shall be handled using software without any need for any potentiometers on the I/O card. As a result, replacement of an I/O card shall not require any recalibration.

5.3.2.25 Connection of I/O system to controllers shall be made by 16-bit Industry Standard Architecture (ISA) Bus, Extended Industry Standard Architecture (EISA) 32-bit Bus preferably or manufacturer's proprietary Bus link.

5.3.3 Data acquisition system

In order to achieve a complete integrated process control system, the DCS shall be equipped with suitable data acquisition sub-system to provide gateways expanding the control system data-base, by linking other devices to the data highway.

5.3.3.1 The data acquisition shall employ an independent interface card to provide translation of acquired signals to DCS data link format and allows RS-232C or current loop connection to foreign devices, such as:

- Programmable Logic Controllers (PLC)
- Gas Chromatographs and any other process analyzers.
- Data loggers
- Turbine and compressor control panels
- Variable speed drive systems
- Burner Management Systems
- Weigh scales
- Tank gaging and Meter-Prover systems
- Any other system supplied on packaged basis.

5.3.3.2 The data acquisition system electronics shall employ fully modular design using state of the art technology.

5.3.3.3 The data acquisition system shall enable the operator to use the DCS console to monitor a programmable controller and control its specified functions through the pertinent PLC interface card.

5.3.3.4 The data acquisition system device shall check all input variables for over-range and under-range limits and transmit relevant alarm signal to the DCS.

5.3.3.5 The data acquisition system shall be equipped with auto-diagnostics routine for checking correct operation of the electronics and producing pertinent alarm signals to the operator console via the data highway.

5.3.3.6 Digital inputs and outputs shall be electrically isolated from internal electronic circuits by dedicated devices, such as optocouplers. Fuses shall be provided for protection of the cards, if specified.

5.4 Man-Machine Interface (MMI)

5.4.1 General

5.4.1.1 Each MMI station shall consist of two independent consoles, two printers, one hard copy device, two redundant hard disc drives, and two dual diskette drives minimally. The exact number of consoles and accessories will be indicated in architectural configuration sheet for each project.

5.4.1.2 The MMI stations shall permit access in different levels, such as:

- **Operator:** The station shall provide possibility to have rapid access to all video pages defined for the engaged operator and shall provide access to all MMI functions necessary to perform the control of the process.
- **Supervisor:** The station shall provide access to all consoles of the system connected, with possibility to monitor and define the responsibilities of each operator station by the supervisor.
- **Engineer:** The station shall provide possibility of start-up and control of particular diagnostic programs, modifying the configuration data, creating new video pages and new control loops by means of a password, if employed.

5.4.1.3 The operator station shall acknowledge all operator actions and indicate acceptance or rejection, in order to, circumvent problems arising by incorrectly pushed buttons, improper entry of point tags or data. For each continuous control loop, the operator interface must allow the operator to perform all of the normal control functions and monitoring the results of these actions.

5.4.1.4 All variables shall be referred by their pertinent tag number through a data base entry interactively. The following man-machine functions shall be provided in all operator stations;

- The frequently used operator functions such as; start/stop, controller mode selection, set-point adjustment, output adjustment, etc., shall be provided with dedicated functional keys.

- It shall be possible to have access to the various DCS sub-systems by any operator console.

5.4.1.5 The following human engineering factors shall be minimally foreseen in the consoles design:

- CRT color saturation and light intensity shall be continuously variable and adjustable, and shall be made accessible to the operator by suitable means.

- The scan frequency and power supply filtering design shall be, in a manner that, stroboscopic effects arising between room fluorescent lighting and screen up-dating be negligible.

- Operator keyboards and CRT positions shall be adjustable to different working positions physically, if specified.

- New CRT display pages invocation shall be completed in one second maximally, static data acquired from disk shall be invoked in three seconds maximally.

- Each station shall be equipped with electronic bleeper for audible alarm annunciation. The bleepers shall preferably be of variable intensity type for identification of selective alarms.

5.4.1.6 The CRT electronics shall support user selectable colors for defining colors of process variables, set-points, outputs, messages, etc. A minimum of 16 colors shall be available. Graphic generation shall be handled by configuring vector graphics on a pixel basis preferably.

5.4.1.7 Selectable strip chart recorders shall be provided for all loops shown on P & ID or indicated in the function list. The operator shall be provided with the possibility to select each of the specified variables and address them to the pertinent recorder by the keyboard at his own discretion.

5.1.4.8 Automatic time synchronisation shall be provided among CRT consoles by real-time clock. The real-time clock shall be crystal type independent of line frequency.

5.4.1.9 Devices operating within the DCS shall be under continuous surveillance by diagnostic routines. In the event of malfunction detection, the operator shall be alerted at the console and the malfunctioning device. System over-loads, such as memory capacity, scan rate, etc., shall be alarmed at the operator station.

5.4.1.10 The MMI stations shall be microprocessor based using 32-bit microprocessor to operate in the multiprocessor environment. The microprocessors shall employ standard EISA Bus preferably for communication between processors,. The processors shall employ an efficient real-time operating system as an environment for application software.

5.4.2 Operator console

5.4.2.1 Each console in an operator station shall be fully independent of others and shall be stand alone type, with it's own electronic circuits and dedicated peripherals, CPU and memory. The operator console shall minimally contain the following devices:

- High resolution, VGA type 19"or 20" color CRT.

- Functional keyboard plus alphanumeric keyboard.

- Dual redundant 120 Mega-byte, minimum each, hard disc drives

- Dual 3½" high-density, 1.44 Mbyte diskette drive (diskette drives for all consoles may be located in a unified compartment)

- Cursor-movement-device of track-ball imbedded in the keyboard or Touch-Screen device.

The consoles shall be fully interchangeable, in a manner that, a failure in any single console does not affect the performance of the operator station.

5.4.2.2 The operator consoles design shall be according to the best human engineering factors, to reduce the instances and effects of human errors, and shall be easy to operate.

5.4.2.3 The operator console shall perform basically the following functions:

- Indication of analog and digital controlled or non-controlled variables.
- Manipulation of control set-point and alarm setting values and also manual, auto, or cascade operation.
- Performing hourly, shift end, daily and monthly average and historical trends.
- Displaying custom displays (interactive schematics).
- Presenting reports and print-outs including display hard-copies.
- Recipe generation for batch process control, if specified.
- System diagnostic reporting.
- Status monitoring of the command execution by the controllers.
- Provide a co-ordinated hierarchial sets of displays, such as:

  menu display, overview display for at least 64 loops per display page, unit display for at least 32 loops, group display for not more than 8 variables, detail displays, trend group displays for 8 variables, single trend displays, interactive, color dynamic control configuration graphic displays, alarm summary display with list of displays, alarm processing and display, controller tuning trend displays (protected by password), system self-diagnostic displays, system hardware status displays, real and historical trends, guide message display, help message display.

5.4.2.4 The overview display variables shall be represented by bar-graphs having a length proportional to their deviation value from the standard setting on a simplified graphic representation of the process. Alarm signals shall also b e presented for each variable at bottom side of the screen. Each alarm point shall have the tag number and status, shown in conjunction with the deviation indication.

5.4.2.5 Group display shall be displayed by pertinent information, such as; tag number, engineering unit, set-point, process variable, etc., as well as, pre-alarm, alarm status, and information on the setting values of the alarms, in a manner, to allow the operator to modify the alarm settings. This information shall also be displayed by bar-graph indications and color coding for visual recognition. Other informations pertinent to each loop, such as; loop status (i.e. AUTO/MANUAL), and loop description (i.e. GAS FLOW) shall be made available on this type of displays.

5.4.2.6 Detail display shall show a bar-graph and tabular representation of the actual value of manipulated variable, control variable, set-point and relevant engineering information pertinent to a specific loop for each operating loop connected to the control system.

- At this level of display hierarchy, the engineering units and configuration values shall be allowed to be changed, by means of, password or hardware keylock to restrict unauthorized access to the loop tuning constants, process variable zero and span, alarm limits and any other configuration details,such as; algorithms, signal types, or input sources.

- The following detail status condition displays shall be accessed by the operator for all discrete signals:

a) Type of device,
b) Tag-number,
c) On/Off or Open/Closed status,
d) Failure to operate,
e) Manual or automatic control mode,
f) Indication of shut-down command issue,
g) Device readiness for failure reset,
h) Instrument faulty condition,
i) Alarm setting,
j) Configuration data,
k) I/O device locations,
l) Indication of any input signal manual over-ride.

- The following commands shall be available to the operator through functional keyboard for analog variables pertaining to each loop;

set-point and output shall be changeable in automatic and manual mode respectively with the following commands,

1) Up (open):
2) Down (close)

Set-Point and output ramping speeds shall be adjustable at operator's convenience.

5.4.2.7 Trend display shall support trends for one, two or three variables simultaneously on the CRT screen with the loop tag-number enabling the operator to monitor the inter-relation between variables (measured variables, calculated values, setpoints,and discrete inputs or states). The display time base shall be selectable within 20 minute period up to 24 hours and trends shall be automatically saved on the operator station magnetic disc media. The process variables specified in the function lists shall be sampled and the instantaneous values shall be stored at intervals of maximally ten second periods. The stored data shall be reproducible on the printer automatically once per eight hour shift and at any time according to the operator request.

5.4.2.8 Trending displays shall be made available for all specified loops in P&ID drawings and the DCS function lists. The display shall have range expansion and compression, zero suppression and elevation, timebase compression and expansion.

- Data shall be updated on point-by-point basis to ensure availability of a stored data at any time.

- Trend data points shall be connected with a continuous trace provided in accordance with pixel resolution of the CRT tubes.

- Continuous scale expansion in 1% increments shall be provided for the operator enabling him to change the display scaling (i.e. going from 0-100% to 25-50%).

5.4.2.9 Dynamic graphic configured displays shall be considered for the system. These displays shall be fully interactive.

- The displays shall be organized in partitioned overlapped pages, in a manner that, each display page contains process information and related instrumentation for up to 64 unique tags, each having multiple dynamic variables presentation.

- The organization of different graphic display pages shall be hierarchial according to the following levels:

a) Overall process,
b) Individual process units,
c) Process unit sections.

- The following information shall be made available on the graphic displays:

a) Measured value for each analog variable,
b) Status of equipment such as; pumps, On-Off valves, packaged equipment, etc.
c) Analog and discrete variable alarms.

- The following interactive operations shall be made available to the operator by display pages;

a) Commands for turning On or Off the pumps, On-Off valves, packaged equipment etc.
b) Setting controller set-points and manipulation of process variables in Manual mode.

- The graphics shall be programmed by vendor based on ISA S5.3 for instrument symbols and ANSI Y32.11 for process symbols. Vendor shall prepare the graphics, on the basis of the simplified graphic display schematics supplied to him for the project after contract award. Multiple color coding (8 colors) shall be provided to indicate alarm points and operating status of motors, fans, valves, etc.

- The ISA S5.3 and ANSI Y32.11 in addition to any other symbols which are used in the graphics shall be made available as insertable block symbols in "system graphical library" for system modifications and future expansions.

5.4.2.10 Alarm summary displays shall present the latest plant alarms and their respective operator reset activation to the operator chronologically.

- Each line of the alarm list display page shall show one specific alarm. This alarm line shall minimally contain the following informations:

a) Alarm occurrence and the time when the acknowledge command has been issued by the operator showing hours, minutes, and seconds.

b) The alarm type such as High, Low, High-High, or Low-Low.

c) Alarm description showing the alarm group page number and the group display and control configuration page numbers which the alarm is associated with.

- The following separate lists with time stamp shall be provided for the system:

1) Active process alarms,
2) Acknowledged process alarms,
3) Active hardware alarms,
4) Acknowledged hardware alarms,
5) Active system alarms,
6) Acknowledged system alarms.

5.4.2.11 Alarm display pages shall be provided for alarm handling by the operator. The alarms shall be grouped into the pages according to alarm groupings provided to the vendor in DCS alarm lists. The system shall manage the alarms and provide the following performance:

- The system shall provide at least four measurement and two deviation alarm levels for each control variable. The level of these alarms shall be definable by the process supervisor.

- The possibility of displaying the alarm status for discrete variables with their pertinent status or value.

- The alarm message shall show the point tag identification and description of the alarm.

- Alarms shall be prioritised by color. They shall preferably be prioritised by position as well.

5.4.2.12 The occurrence of any alarm within the control system and shutdown system shall result the following responses:

1) A change in color of the alarm point status indication in all displays in which it is present;
2) Flashing of the alarm point status indicator until it is acknowledged;
3) Audible annunciation;
4) Print out of the alarms in order of occurrence with details such as; tag number, alarm state indicator, alarm description, trip point value (if applicable), time and date of; occurrence, reset and return to normal.

5.4.2.13 Reports and listings

The MMI shall provide suitable means to document the reports and alarm listings with presentation of the time of occurrence of each item and pertinent designation of sequential events and operator entries. The following process record keeping features shall be provided in the system, as a minimum:

- Operator Entry Report (OER)

A list of all entries actions initiated by the operator affecting control of the process, including; changes in control mode set-point, manual output or logic commands, with the identification of the console which the changes have been made from, with time stamp.

- Event List

A documentary list which presents all discrete events within the system, indicating the time and description of the events. The time stamp resolution of the events shall be better than 100 m Sec. The alarm messages shall be user definable and the length of them shall be minimally 80 characters. The system shall support 10 separate lists minimally.

5.4.2.14 Custom reports

All custom reports shall be stored on the console hard discs, to be recalled at any suitable time. All reports shall be made available by the system printer on operator request and/or on eight hour cyclic shift basis. The following type of reports shall be made available on the system:

- Standard Format Reports

These reports shall be user configurable with ability to include any selected information from any log, event or alarm list. This type of report shall be printable on-demand or periodically.

- Variable Format Reports

These reports shall be user configurable with ability to include any system data, such as; data stored in historical trend files or controller inputs/outputs. It is required that manipulation and calculation to be allowed to generate time-based averages, totalization, minimum values, minimum times, maximum values and maximum times.

5.4.3 Engineering console

5.4.3.1 All engineering parameters pertinent to the loop configuration, control strategies, and control algorithms shall be accessible by engineering console for engineering modifications interactively.

5.4.3.2 The console shall be either a dedicated engineering console or a multitask MMI console as specified in attached project data sheets, and shall be capable to perform the following tasks:

a) Customising the system to meet any specific control objectives at start-up or at any time during operation and initial configuration generation,

b) Assigning tag-numbers to I/O channel to make them addressable by the control system,

c) Inserting scaling and tuning parameters,

d) Setting alarm limits,

e) Creating console display pages,

f) Running diagnostic routines,

g) Storage of configuration (including sufficient Bulk Storage Medium),

h) Copying system configuration onto Bulk Storage Medium,

i) Loading configuration from Bulk Storage Medium into the system,

j) Modifying configuration during system operation without interference to other devices or loops,

k) Help screens and sufficient blank configuration forms.

5.4.3.3 The engineering display shall provide the following types of displays, in fill-in-the-blank forms preferably or by a menu page selection; to be configured on-line:

- Control strategy or algorithm configuration pages,

- Field controller parameter adjustment and Tag-Number assignment pages,

- Different graphic display pages for their configuration editing,

- Trend generation displays,

- Configuring inputs to the system by filling the tag number, tag descriptor, system terminal number, type of signal characterizer, input alarm limits, alarm deadband and engineering units. Multiplexed inputs shall use a single configuration display format.

- Configuring output functions by filling the tag number, function description, system terminal number,output valve (including manual over-ride capability), reverse or direct acting selection and output fail-safe action selection.

- Configuring discrete output functions by filling the tag-number, function description, output status, contact type, output hold option, fail-safe action selection and system terminal number.

5.4.3.4 The console shall provide on-screen forms to configure points and devices in the system by filling-in-the-blank the spaces provided in front of data description headers generated by the system for all variety of control algorithms and strategies.

5.4.3.5 The engineering console shall provide an on-line Help facility to provide enough information to facilitate the programming and auditing tasks at any level encountered in the control system.

5.4.3.6 The auditing software shall be provided in the engineering console to perform checking of all configuration data entered and alert any missing information or any other potential errors made by Engineer.

5.4.3.7 The console shall preferably provide a special auditing software for specialized complex control strategies to recognize the type of instructions entered and prompts for information needed. This program shall also check the data entered for their correctness. Such an auditor shall provide on-line Help messages pertinent to all types of instructions on Engineer demand.

5.4.3.8 Graphic display elements shall be drawn by using library of symbols provided in the system-data base. The graphic software shall provide facilities for symbol rotation, and size selection.

5.4.3.9 The engineering console software library shall include a global data-base software to handle all points data, configurations, and adjustment parameters on hard disc.

5.4.3.10 All information entered shall be saved by engineering console in a global data-base.

5.4.3.11 The system shall be equipped with a relational data-base to store each type of data in a designated area, in a manner that, data retrieval and manipulation can be performed efficiently. The data-base shall permit incorporation of new types of data after original database is set-up at system operation time. The system shall be capable to import/export ASCII formatted data from commercially available data base and spread-sheet programs.

5.4.3.12 The system shall be equipped with necessary softwares to transfer configuration data to control system after completion of all configuration data in system data base or after auditing of the configuration data is completed and saved.

5.4.3.13 A menu selection shall be provided letting the Engineer to choose whether to download specific configuration data to several devices or only to a specific one. In addition, the system shall provide the Engineer with facilities to down-load the entire configuration data for a device or just the configuration changes since the last down-load at his own discretion.

5.4.3.14 In performing the down-loading operation, the system shall preferably extract pertinent information for the device concerned from relational data base and generate a separate file to be down-loaded to the device with all requested options.

5.4.3.15 A language editor software shall be provided in the engineering console to facilitate data base generation by cutting, joining, and copying the existing information for use in other parts of the database. The editor shall also provide the Search and Search-and-Replace functions to find and update data.

5.4.3.16 When modified configuration data is saved by the Engineer, the system shall store it as the current version. The previously downloaded version shall be still stored and made available on hard disk by the system. At downloading

time of the new version, the system shall preferably be capable to compare the old and new configurations and to send only the changes along the Highway to the devices, in order to decrease the data highway occupation time for on-line engineering applications.

5.4.3.17 The engineering console system shall be provided with an automatic tuning program residing on the hard disc unit. The program shall be capable to be run on-line by the Engineer request to tune individual control loops optimally.

5.4.3.18 The controller tuning parameter changes that have been made by automatic tuning program shall be uploaded to be visioned on the CRT by the Engineer and used to keep the data base up-to-date.

5.4.3.19 In addition to the automatic tuning software, a Trace-and-Tune software shall be provided in the system to allow off-line tuning of individual control loops and testing the performance of the pertinent control strategy without affecting the process control operations. Such a task shall be performed by entering simulated analog or discrete inputs for an on-line controller to the Trace-and-Tune routine and observe the controller output. All the key points within a complex strategy shall also be capable to be observed by this Trace-and-Tune program.

5.4.3.20 The system shall also be provided with a diagnostic software to perform the system diagnostics, identifying specific device errors and helping trace the source of intermittent faults. Diagnostic display pages provided by this diagnostic software shall provide extensive coverage of system conditions. The following features shall be provided by this software, minimally:

- A Communication overview display page to show the communication status of all data highway devices. (primary and back-up communication links).

- Detailed integrity displays to examine suspected devices in detail, with sufficient information to identify faults down to the circuit board level.

- Indication of malfunctions that occurs, on the; primary and backup control devices, primary and backup power supplies, peripherals, and continuous indication of throughput traffic on the communication link.

5.4.3.21 To prevent unauthorized access to the console, it shall be equipped with passwords to protect the process from unauthorized configuration changes. The security functions shall preferably provide the following features:

- A general administration password shall be considered for Engineer supervisor. The owner of this password shall be the only person to create or delete data-bases or grant other levels of access right to other maintenance personnel.

- Approved user passwords shall be provided for maintenance personnels. Such level of users can use only the functions specified by the Engineer supervisor using administration password. The extent of the approved user functions shall cover all available functions which some are listed bellow;

a) Creating, deleting, or updating items,
b) Applying diagnostic programs,
c) Using Trace-and-Tune programs,
d) Generating and downloading new configurations.

5.4.4 System keyboards

5.4.4.1 Each console shall be equipped with an alphanumeric keyboard plus necessary functional keyboards. The following requirements shall be foreseen in the keyboards minimally:

- The keyboard shall have a retractable cable to provide the user the capability to position the keyboard wherever he wishes for maximum comfort.

- The following type of keys shall be considered in operator keyboards;

a) QWERTY, ASCII alphanumeric keyboard for engineering consoles,
b) Alphabetic order, ASCIII, alphanumric keyboard for operator consoles,
c) Task oriented keys,
d) Control oriented keys.

- All consoles shall be provided with membrane type keyboards, preferably.

5.4.4.2 The keyboard shall be partitioned in the following distinct functional zones:

a) Display select area,
b) Alphabetic and numeric entry area,
c) Cursor movement area (if applicable),
d) Control area.

5.4.5 Hard copy devices

5.4.5.1 Color video-copier shall minimally fulfill the following technical requirements:

- The copier shall have acceptable quality and reliability and shall be accessible from any operator console.

- The copier shall provide addressability of 154 dots per inch both horizontally and vertically with enough color composition.

- The copier shall use the A4 non-sensitized papers for picture production.

- The copier shall perform the copying in a time interval not more than 5 seconds.

- The copier shall be fitted with suitable cover.

5.4.5.2 A color printer shall be provided to log events and alarms. The printer shall meet the following requirements minimally:

- The printer shall be microprocessor type, high speed and with excellent letter quality.

- The device shall preferably use parallel, nine wire array, matrix print heads to provide bi-directional printing.

- Connection of the printer to the system shall be by an integral serial interface port conforming to RS-232C standard.

- The printer shall support printing of block, character, and line graphics, by means of four color ribbon.

- The device shall accept all types of ribbons such as four color, red/black and black only type.

- The ribbon of the device shall be of commercially available brands.

5.4.5.3 The Bid documents shall identify any capability of generating customised format printouts, if included.

5.4.6 Hard disk memory device (Bulk Storage System)

5.4.6.1 The hard disc unit shall be winchester drive type. The hard disc shall be permanently sealed into the drive and shall not be removable, to be unaffected by environmental dust and smoke.

5.4.6.2 The spindle driving of the disc shall be preferably of direct drive motor type to reduce the number of bearings and provide the drive with more reliable mechanism.

5.4.6.3 An automatic seek truncation shall be provided at inner/outer tracks of the hard disc.

5.4.6.4 The Storage device magnetic medium shall be preferably 3½" aluminum platter, coated with a smooth, polished metallic oxide and shall provide 120 Mbyte minimally formatted storage capacity.

5.4.6.5 A full shock protection counter-arm mounting shall be provided for the device to eliminate head/carriage damage during transportation.

5.4.6.6 The following data must be provided for the Bulk Storage System:

- MTBF and MTTR
- Seak time, latency, etc.
- Back up recommendation or service offered
- Environmental limitations (temperature, humidity, smoke, dust, hydrogen sulfide, etc.)

5.4.7 Flexible diskette drives

5.4.7.1 Removable diskette drives shall be used primarily to store and down-load the programs that:

- Set-Up the file management used in operator stations
- Store the configuration of operating information used by the remote electronic units (controllers)
- To organize the programs that set-up the operator station group overview display
- To store archival trend values
- To store graphics and tabular displays.

5.4.7.2 The magnetic media employed shall be 3½" double high density diskette type preferably.

5.4.7.3 The diskette drives employed, shall be capable to support 1.44 Mega-bytes of formatted storage.

5.5 System Cabinets and Consoles

5.5.1 General

5.5.1.1 The DCS consoles and cabinets shall be manufacturer's standard type and shall be equipped with all necessary equipment.

5.5.1.2 The cabinets and consoles shall be complete with all instruments, terminals, equipment, etc., ready for site installation. The Vendor shall provide all parts, components, and modules, necessary to provide tidy, complete workstations and cabinetry.

5.5.1.3 Marshaling cabinets shall be provided, if requested in purchase order.

5.5.2 System consoles

The consoles shall be complete with all modules, systems, and sub-systems in full accordance with the intent of this specification.

5.5.2.1 The width of the console shall be around 600 mm.

5.5.2.2 The depth of the console shall be around 800 mm.

5.5.2.3 The height of the console shall be around 1500 mm, at the front and around 1300 mm, at the back side.

5.5.2.4 The console shall be equipped with a cabinet to accommodate the electronics with a nominal height of 800 mm, measured from the floor. The cabinet shall have two access doors, one from the front of the console and the other from the back, to accommodate the following modules;

- Power supply unit of the system,

- An EIA 19 inch card file rack to accommodate all electronic circuits of the console, such as; keyboard interface card, recorders interface card or printer interface card, display generator card, Direct Memory Access (CPU) card, memory cards, Highway logic cards, Highway driver/ receiver cards, microprocessor (CPU) card, diskette interface card, etc.

5.5.2.5 The station shall have a writing surface to accommodate the keyboard and function keys with nominal depth of 300 mm at height of 800 mm measured from the floor.

5.5.2.6 By the side or under the CRT the dual floppy diskette drives shall be installed.

5.5.2.7 The steel-work shall be painted by stove enameled method with texture finish in sea green according to BS-381C, shade 217.

5.5.2.8 The power and control cables shall enter from the bottom of the consoles.

5.5.2.9 The vendor shall provide standard filler plates to make the consoles uniform and integrated as a complete operator station.

5.5.3 System cabinets

5.5.3.1 The cabinets shall be welded steel enclosure type.

5.5.3.2 The cabinets shall house remote mounting auxiliary equipment, controller cards, plus any kind of rear panel mounted equipment, as well as, interconnecting wiring and instrument power supplies. Marshaling racks shall be housed in the cabinets, when requested in purchase order.

5.5.3.3 The components inside the cabinets shall be located in an optimum position for operation and servicing.

5.5.3.4 The Cabinets housing the electronic circuits and controller cards shall be provided with a suitable capacity, circulation fan.

5.5.3.5 The Cabinets shall be equipped with EIA 19" racks for housing electronic circuit cards.

5.5.3.6 The Cabinets shall have standard arrangement and the following nominal dimensions:

Height	**2000 mm**
Width	**600 mm**
Depth	**600 mm**

5.5.3.7 The enclosure doors shall satisfy the following requirements:

- The height and width of the enclosure doors shall be at least fifteen millimeters (15 mm) greater than corresponding height and width of the enclosure opening.

- A permanent metal drawing pocket shall be welded to the inside surface of the door. The drawing pocket shall be 300 mm wide with 70 mm depth.

- Doors of the enclosure shall be designed to have sufficient rigidity to conserve alignment between mating parts.

- Doors shall be equipped with door fasteners and locking devices.

- Opposite access doors (if required), shall be provided for cabinets, for ease of maintenance.

- Doors swing shall be minimally 165° and shall be attached to the enclosure body with a continuous hinge.

- Neoprene door gaskets shall be attached to the doors with oil resistant adhesive materials and held in place by means of steel restraining strips to increase enclosure protection against dust and water.

5.5.3.8 Cable entrance shall be incorporated at the bottom of the panel by means of gland plate, made of steel plate minimally 5 mm thick and shall be removable with suitable screws.

5.5.3.9 All cabinets shall be provided with suitable temperature sensor with DCS alarm for detecting abnormal temperature inside the cabinets.

5.5.3.10 Terminals shall be mounted on sides of the enclosure to be connected to field instruments. Minimum distance of terminals from floor shall be suitable for ease of maintenance.

5.5.3.11 Terminals on the terminal block shall be plainly and permanently marked with the identification tags shown on electrical diagrams correspondingly. Only two terminations per side of a terminal is permissible.

5.5.3.12 Conductors shall be identified at each termination by the same tag as the terminal by means of wire sleeves, made of oil resistant material.

5.5.3.13 Conductors and cables shall be run from terminal to terminal without splices.

5.5.3.14 The wiring of the cubicles shall be run in suitable wireways.

5.5.3.15 Terminal blocks shall be mounted and wired so that the internal and external wirings do not cross over the terminals.

5.5.3.16 The conductors used shall be all of extra-flexible, stranded copper, PVC insulated, 75°C type.

5.5.3.17 Provisions shall be made for grounding of the enclosure.

5.5.3.18 At least 40% of terminals and 20% of card files shall be considered as spare for future expansion in each enclosure.

5.5.3.19 The cabinets shall be provided with louvers and removable anti-dust filters, and shall have a sealed bottom in order to avoid dust infiltration in final arrangement.

5.5.3.20 The cabinets shall be painted by stove enameled method with texture finish in Sea Green Color according to BS 381C shade 217.

5.6 Data Highway Interface to Automation Computer System

5.6.1 The DCS shall be capable to be interconnected in higher level automation network by data highway interface. The interface shall be capable to perform the following functions minimally:

- The communication between computer and DCS shall be based on DCS master/computer slave principle.

- The DCS shall allow for the full transfer of the data bases resident in the system to the computer system without any limitations.

- DCS shall be capable to accept the computer system messages and commands in a separate dedicated data-base to be further evaluated and transferred to the control system by specialized softwares; (reference shall be made to pertinent project requirements)

5.6.2 General computer interface

5.6.2.1 The DCS data highway computer interface shall use either Eternet TCP/IP, Decnet, synchronous X.25 or asynchronous ASCII, to interface to any type of computer supporting an ASCII terminal driver at information rate of 300 baud up to 58 K baud. The system shall support interface to any commercially available automation computers. This general computer interface shall be configured from the DCS console, so there is no need for two separate operator consoles.

5.6.2.2 In order to simplify the establishing of communication links between the computer and the DCS, the DCS vendor shall provide an extensive list of instructions, easily implemented in standard FORTRAN statements, C Language statements, or BASIC program statements. A sample program and a list of instructions shall be included in the vendor's proposal to be evaluated by Company.

5.7 Interface to Programmable Logic Controllers (PLC)

5.7.1 General

The purpose of the PLC interface is to provide operator with the required data from the PLC. This feature shall be accomplished by displaying the data, primarily in the form of custom-built graphics, at any DCS console. The DCS shall also be capable of displaying the PLC data in the form of trends or custom reports.

5.7.2 The PLC interface design and variety of the sub-system shall enable interfacing of the DCS to the most major manufacturers of the PLC, as listed in Company's approved vendor list. The interface shall preferably support MAP/ OSI standard as outlined under ISO codes in section 2 or Ethernet TCP/IP protocol.

5.7.3 The DCS communication with the PLC shall be implemented by means of RS-232C connectors. Communication between the interface card and the operator console shall be established via DCS data highway.

5.7.4 Diagnostic routine alarms of the PLC shall also be transmitted to the DCS and operator console by the same PLC interface card.

5.7.5 The PLC interface shall have continuous Read and Write capability to maximize throughput and shall support simple mapping of any PLC registers into the DCS.

5.7.6 A single PLC interface shall be capable of supporting multiple PLC's on multi-drop basis.

5.8 Electrical Requirements

5.8.1 Power supplies

5.8.1.1 The DC power supply system shall be designed to meet the power requirement of the DCS and all two-wire field instruments. Each power supply shall be sized, such that, not carry more than 75% load of it's capacity under normal condition. Separate AC circuit breakers shall be provided for each power supply. The control system will be supplied with 110 Vac power from an Inverter/UPS system, unless otherwise specified.

5.8.1.2 DC power sub-system, including inputs to the controller and DCS sub-systems shall be dual redundant. Failed power supplies must be removable without disconnecting power from any part of the system or affecting control operations.

5.8.1.3 All DC power required to excite external transmitters and drive external transducers shall be drived from power supplies within the DCS I/O system.

5.8.1.4 The power supplies must be over-current and over-voltage protected.

5.8.2 Integral power back-up

5.8.2.1 Integral battery back-up shall be considered to maintain power for the controllers, I/O signal conditioning devices and two-wire field instruments for a minimum period of 60 sec., upon loss of all DCS power.

5.8.2.2 Batteries shall be auto-tested once every 8 hours.

5.8.3 Power system indicators

5.8.3.1 The DCS system shall be capable of monitoring and reporting the status of AC power supplies and battery back-up conditions to the operator. Output current of the power supplies shall be indicated, in order, to confirm that supply capacity has exceeded. Blown fuse indication shall be provided on the face of all system cards if they are equipped with such a feature.

5.8.4 Transient, static and RFI protection

All DCS electronic circuits shall be internally protected against system errors and hardware damages resulting from the following causes.

5.8.4.1 Connecting and disconnecting devices, removing and inserting printed circuit boards or cables including removal of data highway connections while the system is operational shall be limited to the loss of disconnected equipment only.

5.8.4.2 Electro-magnetic radiation

The Vendor shall quote and specify the following information in his bid proposal, regarding sensitivity to electromagnetic radiation;

- frequency range,
- transmitter power level,
- distance or proximity of the source to transmitter,
- effect on the control system operation,
- methods used to determine the above results.

5.8.4.3 The control system shall not radiate any interference to any other equipment or system present in the plant.

5.8.5 Equipment connection

5.8.5.1 All interconnections between components of the system (including the Data Highway) shall be via prefabricated (to length) and predetermined cables supplied with the system.

5.8.5.2 All plugs, receptacles and cables must be clearly, uniquely and permanently lablelled.

5.8.5.3 All plugs, in cables and devices (including circuit boards) must be keyed to prevent incorrect connection. A suitable locking device must also be provided to prevent accidental disconnection. Circuit boards shall be guided for insertion and include permanently attached extraction device to assist in removing the cards.

6. SOFTWARE REQUIREMENTS

6.1 Control Software

The following software subroutines shall be made available in the system, as a minimum:

A. Control algorithms

- PID (linear)
- PID (non-linear)
- PID (ratio)
- PID (floating)
- Adaptive tuning
- Differential gap control
- Proportional time control
- Motor control
- Supervisory control
- Auto-Manual mode control

B. Computational algorithms

- Summer
- Multiplier
- Function generator
- Dead time
- Median
- Lead/lag
- High select/Low select
- Mass flow
- Square root
- Log function
- Exponential function
- Accumulator
- Characterizer

C. PID functions

- Output limiting
- Output tracking
- Feed forward
- Anti reset wind-up
- Set-Point clamping
- Set-Point ramping
- Auto-scaling
- Cascade

D. Input/Output algorithm

- Analog input
- Analog output
- Digital input
- Digital output
- Multiple analog input
- On/Off output (MOV)

E. Logical function algorithm

- Timer
- Counter
- Flip-Flop
- Sequencer
- AND
- OR
- NOT
- EXCLUSIVE OR

6.2 Miscellaneous Application Software

The following application softwares shall be provided by the Vendor, as specified:

- Mathematical library
- Physical properties library
- Histogram software
- Report sheet producing software
- Process modeling softwares
- Batch plant management softwares
- Real time data-base manager
- Steady-State optimizer program
- Real-Time self-diagnostics softwares

6.3 Operating System

6.3.1 The operating system of the DCS shall be preferably of "Open" type such as UNIX.

6.3.2 Operating system with X-Windows is a privilege in evaluating the vendor proposal since this OS allows application software and users to interact on "as need" basis.

7. DOCUMENT AND DRAWINGS REQUIREMENT

The Vendor shall supply documents and drawings at different phases of the project engineering execution with quantity and quality requested in this specification and the particular conditions of the Contract.

7.1 Document and Drawing to be Submitted by Bid Proposal

7.1.1 Tender documents shall be carefully studied by the supplier and the requested data marked as "by Vendor" in data sheets, shall be filled-in and submitted by bid documents. The following documents and drawings shall be signed and submitted by the tender documents;

- DCS function list,
- Alarm lists,
- P&ID,
- Control hardware and software requirements.
- Control buildings layout,
- This standard specification,

The above documents shall be completed with the requested data by vendor and submitted as technical part of the bid documents.

7.1.2 The supplier shall read this Standard specification and attached documents/drawings carefully and submit his deviations to these documents under the item, "supplier points and deviations to technical specification". The following documents shall be submitted by the bid proposal for evaluation;

a) Description of the system proposed, including a system configuration drawing indicating all components,

b) Technical descriptive catalogues for each component of the system proposed,

c) List of components proposed with specification, i.e. type, manufacturer, quantities, etc.,

d) Electrical requirements such as; feeding voltages, absorbed power at start-up and at steady conditions (subdivided per each component), maximum time of electrical failure to conserve the system operations without shutdown or malfunction,

e) Generated heat (KJ/SEC.) for each major component of the system,

f) Dimensions and layout of each component,

g) Maximum constructional load per square meter for cabinets and consoles,

h) Vendor project organization and implementation procedures,

i) Vendor's subcontractors and suppliers,

j) Previous and current projects of a similar nature, described in terms of;

- Project and owner,
- Description of system provided by vendor,
- Start and completion date,
- Contact person and address,

k) Description of facilities in which the work will be:

- Engineered;
- Manufactured;
- Staged and tested;

l) Points count list,

m) Deviation lists.

7.2 Documents/Drawings to be Submitted for Approval

The following documents shall be submitted after contract award, according to the agreed time-schedule to be approved by the Company:

a) Feeding and earthing electrical diagrams,
b) Vendor suggested system configuration,
c) Proposed graphic display pages,
d) Proposed logging and report formats,
e) Detail shop test (FAT) procedure for the DCS system,
f) Sample page prints of all DCS pages,
g) Layout of cabinets and consoles,
h) Wiring references for interconnection between DCS cabinets and instruments or marshaling racks with I/O assignments in a tabular format.

7.3 Final Drawings/Documents to be Supplied by Vendor

The Vendor/Supplier shall prepare the hereunder mentioned documentation in quantity of copies as requested in contract document/drawing schedule and contractual purchase order. All these documents shall be numbered according to the project documents numbering criteria.

7.3.1 Documents

Minimally five copies and one reproducible of the following Vendor documents shall be provided:

- Final loop diagrams developed on the basis of the tender documents incorporating all Company's comments, indicating all elements and information pertinent to field instruments and system's equipment.

- Final feeding and earthing electrical diagrams,

- Final electrical loads and dissipations,

- Final configuration lists,

- Final logging and report formats,

- System final technical specifications,

- Recommended spare parts list with their pertinent manufacturer's stock number for commissioning period and two years of operation.

7.3.2 Softwares

7.3.2.1 Minimally 6 (six) copies of the following information shall be provided on floppy diskettes:

- Complete final system configurations,
- Complete system application softwares,
- Basic configuration softwares,
- Complete graphic display pages,
- Final logging and report formats.

7.3.3 Manuals

7.3.3.1 Minimally five copies and one reproducible of the following Manuals shall be provided;

a) Operator's manual, including operating guide for the system's softwares (both standard and application softwares),

b) Engineering and user's manual describing how the work may be modified in the future, and how the work is presently configured. This manual shall include all system components technical specifications,

c) Maintenance manual describing how Company's electronics maintenance personnel can perform; preventive maintenance, troubleshooting, repairs, additions, deletions, and modifications of system configuration. This manual shall include spare parts list with their pertinent manufacturer's stock number. All error codes shall be comprehensively listed and explained in maintenance manual.

7.3.3.2 The above manuals shall be provided for each component of the DCS, including operator's consoles, process control units, communication devices, peripheral devices, etc.:

- Procedure for re-start after power failure,
- Procedure for periodic adjustments by operators and maintenance personnel,
- Technical description and theory of operation,
- Installation procedure,
- Maintenance and troubleshooting procedure,
- Schematic and logic diagrams,
- Procedure for calibration of all I/O,
- List and descriptions of all system error messages,
- Any drawings required for this maintenance and operation manual,
- Printed circuit board component layouts,
- Component interconnection procedures,
- Parts lists,
- Procedure for adding, deleting, and modifying I/O points,
- Procedure for board-swapping and component-swapping,
- Guideline for graphic and report pages; addition, deletion or modification.

7.3.3.3 All Manuals shall be well-organized and easily understood, and shall contain comprehensive tables of contents and alphabetical indices. Topics for each of the hardware components shall include, but not limited to the following:

- Operation procedures,
- Commissioning and start-up procedures.

7.3.4 Drawings

7.3.4.1 Minimally five copies and one reproducible of the following drawings shall be provided:

a) System Configuration Drawing

This shall illustrate the central control configuration, the communications configuration, and the controller configurations, on one drawing, if possible;

b) Operator's Console Layout and Construction Drawing

This shall be scale drawing of the operator's console, showing front, side, and top perspectively. Locations of the various components (i.e. video displays, keyboards, communication panels etc.), shall also be shown with dimensions. Electrical connections and wiring shall be illustrated and described on separate drawings.

c) Cabinet Layouts and Construction Drawing

Cabinet layout and construction drawings shall be provided for all cabinets supplied by the Vendor. This shall include each controller cabinet, computer, disk, communications, and terminations cabinet. The drawings shall be to scale, and shall illustrate all components in each cabinet and their electrical interconnections, and cabinet mechanical mounting specifications;

d) Termination Schedule

This drawing shall list and illustrate all terminations, indicating; terminal/connector numbers, tag names, voltages, currents, polarities, and grounding/shielding requirements. This drawing shall be provided for terminal strips and for any cable supplied by the Vendor.

7.3.4.2 System Vendor shall provide reproducible CAD generated "as-built" mechanical and system interconnection drawings. These drawings shall identify I/O assignments by tag number in a tabular format.

7.3.5 The above Vendor documentation and drawings shall be provided after completion of Factory Acceptance Test before shipment.

8. TRAINING

8.1 The system supplier shall provide Company's personnel with adequate training for equipment maintenance and operation,in order to get them familiar with the system. The Vendor shall provide a description of the training courses available for his system with the duration and cost of each course by his bid quotation for evaluation. The training courses shall minimally provide the following courses:

a) Operation of the system for operators
b) Maintenance of the system for technicians
c) System introduction and basic configuration
d) Advanced system maintenance and configuration for engineers

8.2 The training shall be provided before DCS installation on site. The courses shall be scheduled so as not to be concurrent; so that one person may attend all courses.

8.3 Each course shall be described in terms of;

- Location,
- Duration,
- Schedule,
- Prerequisites,
- Training facilities provided.

8.4 The cost for training shall be included in the contract price but itemized separately.

9. SERVICE AND PARTS AVAILABILITY

9.1 The system Vendor/Supplier shall have spare parts stock in Iran or guarantee to provide the required parts not later than 4 days from the date of request, by Telex or Fax.

The Vendor shall have qualified service personnel which can promptly assign them to the job site for repairs, adjustments, assistance in problem determination and trouble-shooting at a reasonable cost. The price of such a service shall be quoted in Bid proposal for evaluation and economical considerations by the Company, on the manday basis.

9.2 The Vendor shall be technically responsible for all installation, commissioning, and start-up work.

9.3 The Vendor shall provide such on-site services as may be required during installation. Qualified Vendor personnel shall be on call and available immediately for telephone consultation 12 hours per day, 7 days per week, and shall arrive on site within one working day after having been so requested by the Company.

10. SHOP TESTS FOR DCS

The DCS Vendor shall submit his own test procedures for all hardware and software supplied based on the requirements specified herein. No material or equipment shall be shipped, unless all required tests successfully conducted and so certified by the Company's assigned inspector. Vendor shall include heat soak test in his test procedure, as well.

10.1 Factory Acceptance Test (FAT)

10.1.1 General

The tests shall demonstrate the functional integrity of all hardwares and softwares. Company assigned inspectors shall inspect the performance of all tests and they shall have access right to all facilities involved in the manufacturing of the equipment purchased under this specification. The Vendor shall maintain and/or replace any hardware or modify the softwares, if the specified functions are not satisfactorily performed in (FAT) on the Company's inspector judgment. A detailed, scheduled factory test (FAT) procedure shall be submitted in the bid proposal by vendor. Vendor shall provide all necessary personnels and test equipment to perform the tests as, and when required with the costs included in the bid prices and separately indicated.

10.1.2 Quality assurance tests

10.1.2.1 Quality control shall be as per manufacturer's quality control standards to assure good performance of components/modules used in the system.

10.1.2.2 The sampling procedure for the tests will be defined by Company's assigned inspectors.

10.1.2.3 System pretests

The Vendor shall check the workmanship and shall perform all his routine tests on the system prior to power-up of the system .

10.1.2.4 Vendor shall check all the functions of the DCS hardware and software including diagnostic software, at system and sub-system level by simulating the inputs and outputs.

The second check will be the calibration check of all signal conditioners, alarm setters, and other components which affect the accuracy of the loops for their correct calibration according to the requirements. All of these calibrations shall be performed and logged in the record book of power test to be reviewed by the Company.

10.2 Final Acceptance Test

The Company's assigned inspectors will supervise this phase of the tests to be performed on all hardware and software of the system. The necessary manpower and co-operation shall be provided by the Vendor, as well as, all measuring instruments. All sub-systems shall be interconnected as "per actual" interconnecting configuration in the field. DCS vendor shall use simulators to simulate the various inputs and measure the outputs through proper approved measuring instruments.

10.2.1 Detail of final acceptance tests

Followings are details of testings to be performed by the vendor and witnessed by the Company's assigned inspectors. The Company's inspectors shall have the right to perform any of these tests; themselves, ask for re-performing any test, or ask for additional test as included in the Vendor's test procedure proposal.

10.2.1.1 Visual and mechanical tests

Company's inspectors will carry out visual and mechanical testing in principle to assure correct, proper and good workmanship of the equipment.

10.2.1.2 Functional tests

Functional test shall include simulation of each type of input/output to testify the proper function and response of the equipment. The following tests shall be included, as a minimum:

- Complete loading of the system configuration.

- Performance test of all controller functions.

- Measurement of scan-time of controllers and process interface units.

- Checking of data-bases configuration, range, alarm limits, engineering units, etc., to be in accordance with the specifications.

- Checking of all CRT displays for their conformity to the drawings and proper quality.

- Checking the function keys to include all functions required and specified.

- Checking CRT refresh time, data-base update rate, and display changing time to be adequate. The Vendor shall trim the configuration to meet the requirements, in case that, the above mentioned times are inadequate to meet the requirements.

- Checking of redundancy features as per the contract final specification.

- Checking of diagnostic routines for all sub-systems with the faults simulated by Company's inspectors request, and reviewing the diagnostic alarms at console level and alarm log level.

- Checking the proper functioning of peripheral units.

- Checking all system features

- Checking of interfacing software for foreign devices,such as; tank gaging, packaged units, automation computer system, etc., by means of simulation of these instruments.

- Simulation of power failure and restart procedures.

- Checking of all formats and reports for logging, alarm/event printings.

- Checking of spare capacity in terms of hardware, memory, and software to meet the requirements stated in the contract final specification.

- Checking of special control strategies and advanced control by connecting the DCS to the process automation computer (if applicable).

- Checking of maintenance functions and troubleshooting procedures.

- Random sample calibration check for I/O, signal conditioner, etc.

10.2.1.3 Performance test

After completion of checkings mentioned here-above, the entire system shall be remained energized for 72 hours continuously, with hands-off from the system. The system performance for given simulated I/O's shall be only observed during this 72 hour period.

Any malfunction of any kind shall be noted as "Observations" in the final acceptance test report to the Company. If any fault is observed in performance test, the test shall be reconducted after maintaining of the fault.

10.2.1.4 Configuration documentation

All the latest configurations and data-base, as performed during acceptance test shall be transferred on floppy diskettes (two copies) and shipped with the DCS.

10.3 Test Records

Each test carried out shall be formally recorded. Any deficiency or problem found in equipment shall be corrected by the Vendor with replacing brand-new tested parts. Any change in configuration or data shall be clearly recorded in Test log books.

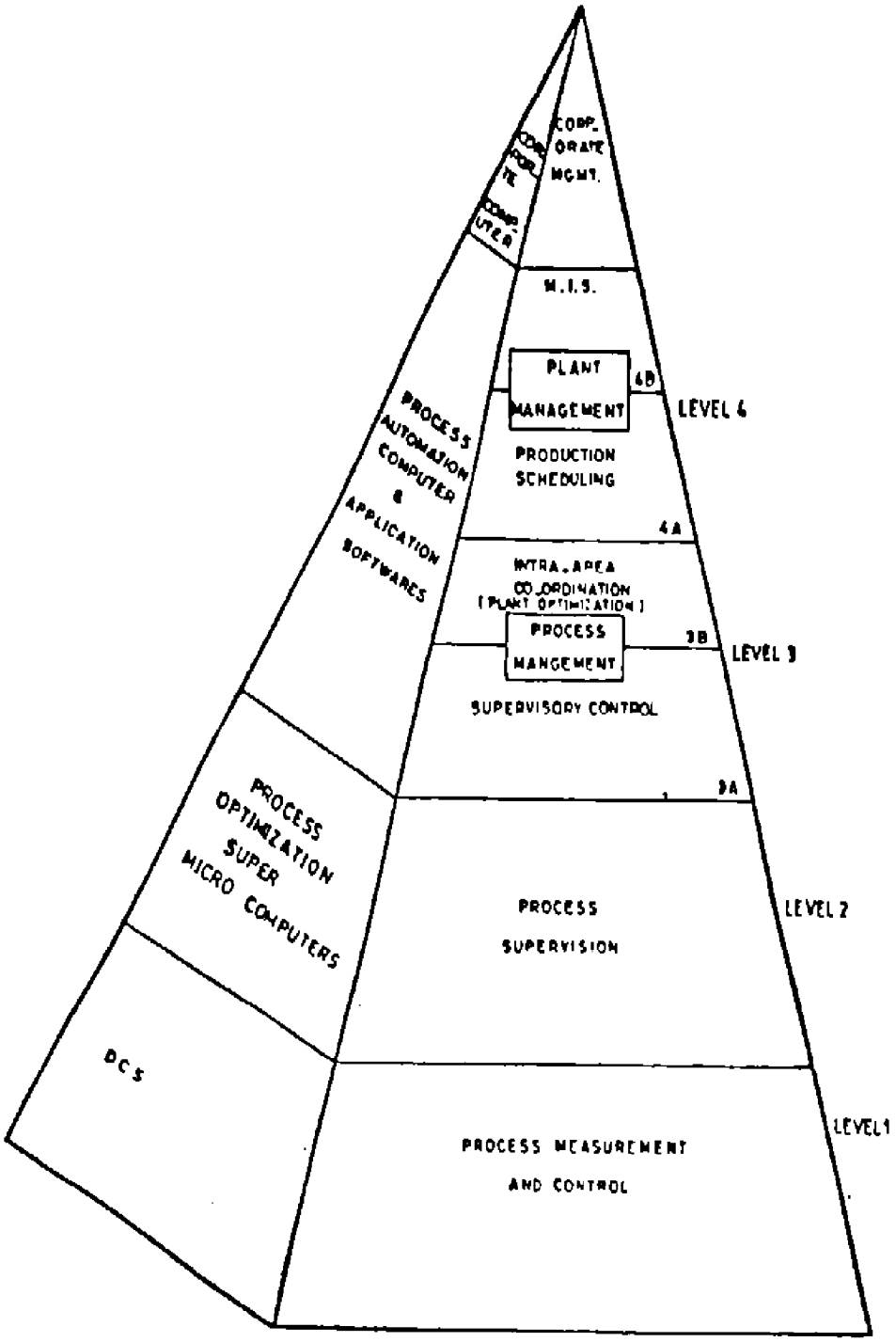
10.4 Conclusion

All FAT reports shall be presented to the Company's assigned inspectors for his signature and issuance of certificate of shipment on satisfactory completion of witnessing the tests. Vendor shall properly pack the system according to shipping instructions and packaging specifications IPS-G-GN-210 and forward the equipment to the Company's site.

APPENDICES

APPENDIX A

COMPUTER INTEGRATED MANUFACTURING (CIM) MULTIPLE LEVELS OF PROCESS EQUIPMENT AND INFORMATION



APPENDIX B
RELIABILITY ESTIMATION DEFINITIONS AND ASSUMPTIONS

The measurement for reliability estimation shall be expressed in terms of Availability, Failure rate, Mean Time Between Failure and repair duration time (Mean Time To Repair). The data used to calculate the above mentioned terms shall be universally accepted predictions (i.e. Mil-STD-Handbook 217 predictions), which quantifies expected useful life of components, utilized under real service conditions.

a) mean time between failure (MTBF) estimation

MTBF shall be calculated by the following equation:

$$\mathbf{MTBF} = \frac{\mathbf{1}}{\mathbf{R1 + R2 + ... + Rn}}$$

R1 through Rn are the failure rates of components used in the equipment or system.

The MTBF calculation for each equipment used and the whole components shall be submitted for evaluation in each bid proposal.

b) failure rate estimation

The cumulative probability of failure shall be expressed as an exponential decay function, in the form of:

$$\mathbf{R = e^{-rt}}$$

Where R is the probability that the system operates without failure in a duration indicated by time t, and r is the failure rate for the class of device as extracted from generally accepted predictions (i.e. Mil-STD. HDBK 217).

c) repair duration time (MTTR)

The DCS vendor shall provide his certified (MTTR) which will be the measure of repair duration time. Such a document shall indicate the skills, test instruments and repair spare stocks required to achieve the stated MTTR.

d) availability

Steady state availability shall be calculated as a fraction of time which the system is operational and shall be expressed as:

$$\mathbf{A = MTBF/(MTBF + MTTR)}$$

For serial subsystems the overall availability shall be calculated by the equation:

$$\mathbf{A = A1.A2 .....An}$$

and for parallel subsystems the net availability will be estimated by the equation:

$$\mathbf{A = 1 - [(1-A1) (1-A2).....(1-An)]}$$