component supplier trainers and in local language.

(2) The training shall be by way of classroom and practical sessions and the content of the training shall include but not be limited to the following:

i) Instruction and hands-on training of starting and shutdown procedure.

ii) Instruction and explanation of all the devices on the Crane (separately for electrical andmechanical staff).

iii) Instruction of Startstop procedure and checking points of all the devices or systems onthe Crane.

iv) Lectures on electrical/electronic control systems of the Crane and adjustment method/standards both in a classroom and on the Crane.

v) Lectures on mechanical/hydraulic systems of the Crane and adjustment method/standardboth in a classroom and on the Crane.

vi) Lectures on Condition Monitoring System on the Crane and in a classroom.

vii) Inspection and Maintenance of Operationally Critical Components.

viii) Instruction on trouble-shooting and repair.

ix) Instruction on emergency equipment and procedures, such as Emergency stop buttons,
Escape route, Firefighting equipment

x) Instruction on the use of equipment for Communication

xi) Instruction on routine maintenance of devices and preventive maintenance plan, includingexplanation of special tools, gauges or jigs.

For this project, mechanical maintenance training shall be provided for 3 groups of 5-8 maintenance staff per group, for 1 week per group. Electrical maintenance training shall be provided for 3 groups of 5-8 maintenance staff per group, for 1 week per group.

(3) Specialist training on the following operationally critical components shall be arranged by the Contractor and to be provided by the component suppliers representatives:

i) Telescopic Spreader (min. 2 days)

ii) Elevator (min. 1 day)

iii) MV and Spreader Cable Reels (min. 1 day)

iv) Cable chain (min. 1 day)

v) Merford Cabin

vi) Service and Emergency Brakes

vii) Wire ropes

7.9.4. Familiarization On-Site (Operators)

(1) The Contractor shall carry out the operator familiarization of the Purchaser's staff during the on- site commissioning period following the Tests on Completion of the Crane(s) or other Works. The familiarization shall be conducted by suitable

Contractor personnel and in local language.

(2) The familiarization shall be by way of classroom and practical sessions and the content shallinclude but not be limited to the following:

i) Instruction and hands-on training of the cranes start-up procedure.

ii) Instruction on lighting control.

iii) Instruction and hands-on training of normal container handling operation in the cab.

iv) Instruction and hands-on training of normal shutdown procedure.

v) Instruction on the use of equipment and procedures for emergency, such as Emergencystop buttons, Escape route, Firefighting equipment

vi) Instruction on the use of equipment for Communication

For this project, operator's familiarization shall be provided for 4 groups of 3-4 operators per groupfor 2-3 days per group.

2.10. Spare Parts

7.10.1. Ordered Spare Parts

(1) Typically, spare parts will be ordered for each crane purchasing contract. For definition and the requirements, refer to the Conditions of the Tender / Contract.

(2) The Contractor shall warrant its capability for providing spare parts, spare components, repair and/or replacement services for a period of 15 years after the date of issue of the Taking-over Certificate for each Crane.

(3) In the event spare parts support cannot be offered for 15 years, the Contractor shall replace the respective parts with "new generation" replacement components bearing the cost of any retrofitting, engineering and design.

7.10.2. Spare Parts for Commissioning Work

(1) The spare parts for the commissioning work shall be provided by the Contractor in addition to the Ordered Spare Parts. The amount of spare parts for the commissioning works shall be comprehensive to assure a smooth commissioning in case a component fails. The Contractor shall not rely on the Ordered Spare parts for the crane commissioning. A draft list of spare parts for the commissioning works shall be provided by the Contractor to the Engineer during the design review period for his review.

(2) The Contractor shall indemnify the Purchaser against any cost, loss or damage if the operational Crane(s) suffers stoppage due to the unavailability of an Ordered Spare Parts which has been consumed by the Contractor during the commissioning period and not replaced before the issue of the Taking-over Certificate.

2.11. Crane Model

(4) The Contractor shall provide two (2) scale models of the crane(s). The models shall be 1:200 scale and shall bear the specified crane livery and logos.

3. APPENDICES

1. Stipulated Components

Note: * denotes the items which constitute "Major Stipulated Components" for purpose of milestone paymenttriggers.

Item No.	Description of Stipulated Component	Stipulated Suppliers for Item	Tenderer's Preferred Supplier Chosen from Stipulated Suppliers
	Structure Steel, main structures	EU, USA, Japan China and Korea with additional certification	A709-50-2 made in China for main structure , flanges, stiffeners and web plates.
	■ Plates and structure sections ≥35mm thickness	EU, Japan, Korea	
	Structure Steel, secondary structures	EU, USA, Japan China and Korea with additional certification	Q235 made in China for subsidiary parts, attachments, platforms, stairs, ladders, handrails, shape steels
	Paint	International, Jotun, Hempel	International
	Spreader *	Stinis	Stinis
	MV switchgear *	Siemens, ABB	ABB
	MV transformer(s) *	Siemens, ABB	ABB
	Drive Inverter System *	Siemens, ABB	Siemens
	PLC & Remote I/O's	Siemens, ABB	Siemens
	LV switchgear components	Siemens, ABB	Siemens
	Electrical System Integration	Crane manufacturer, System Supplier	
	Drive Motors *		
	■ Main Hoist	Siemens/Wolfer	Siemens
	■ Boom Hoist	Siemens/Wolfer	Siemens
	■ Trolley	Siemens/Wolfer	Siemens
	■ Gantry	Siemens/Wolfer	Siemens
	Gear Reducers *		
	■ Main Hoist	Flender, Sumitomo, ZPMC	
	■ Boom Hoist	Flender, Sumitomo, ZPMC	
	■ Trolley	Flender, Sumitomo, ZPMC	
	■ Gantry	Flender, Sumitomo, ZPMC	
	Brakes *		
	■ Main Hoist (Service)	Pintsch-Bubenzer	Dellner-Bubenzer
	■ Main Hoist (Emergency)	Pintsch-Bubenzer	Dellner-Bubenzer

	■ Boom Hoist (Service)	Pintsch-Bubenzer	Dellner-Bubenzer
	■ Boom Hoist (Emergency)	Pintsch-Bubenzer	Dellner-Bubenzer
	■ Trolley (Service)	Pintsch-Bubenzer	Dellner-Bubenzer
	■ Trolley (Holding brake)	Pintsch-Bubenzer	Dellner-Bubenzer

Item No.	Description of Stipulated Component	Stipulated Suppliers for Item	Tenderer's Preferred Supplier Chosen from Stipulated Suppliers
	■ Gantry (Service)	Pintsch-Bubenzer	Dellner-Bubenzer
	■ Gantry (Wheel)	Pintsch-Bubenzer	Dellner-Bubenzer
	■ Hydraulic Power Packs	By brake manufacturer	By brake manufacturer
	Couplings		
	■ Main Hoist Drum	Malmedie	Malmedie
	■ Boom Hoist Drum	Malmedie	Malmedie
	■ Trolley Rope Drum	Malmedie	Malmedie
	■ Brake Disc Couplings	By the stipulated brake supplier	By the stipulated brake supplier
	■ Other transmission couplings	Contractor to propose	
	Hydraulic systems (other than		
	■ Main components	Rexroth, Vickers, Parker	Rexroth, Vickers, Parker
	■ Cylinders	Contractor to propose	
	■ Hydraulic system integration	Contractor to propose. (Chinese brand seals not allowed)	(Chinese brand seals not allowed)
	Bearings	NBI	NBI
	■ Main hoist, trolley, boom hoist and gantry reducer ■ Main hoist, trolley and boom hoist sheaves ■ Catenary trolley sheaves ■ Main hoist drum pedestal ■ Trolley drum pedestal bearing ■ Boom hoist drum pedestal bearing ■ Trolley wheels ■ Trolley horizontal wheels ■ Catenary trolley wheels ■ Catenary trolley horizontal wheel	All Bearings in list must be of European origin, if any bearing cannot be imported from Europe due to supplier's Global fabrication plan, Contractor shall provide a statement from bearing supplier stating the following: 1. Both European made and non-European made bearings are under same quality control system 2. The selected non-European made bearing cannot be manufactured in Europe factory and the origin would be decided by supplier itself.	All Bearings in list must be of European origin, if any bearing cannot be imported from Europe due to supplier's Global fabrication plan, Contractor shall provide a statement from bearing supplier stating the following: 1. Both European made and non-European made bearings are under same quality control system 2. The selected non-European made bearing cannot be manufactured in Europe factory and the origin would be decided by supplier itself.
	■ Gantry wheels	NBI	NBI
	■ Other bearings		
	Auto-Lubrication System	Groeneveld.	NBI
	Intelligent Status Monitoring System	Leewell	Leewell
	Lightning and surge protection	Leewell	Leewell

Item No.	Description of Stipulated Component	Stipulated Suppliers for Item	Tenderer's Preferred Supplier Chosen from Stipulated Suppliers
	Rail Clips	Gantrex, Gantrail	Gantrex
	Buffers	Oleo	Oleo
	Wire Rope	Casar / Bridon / Teufelberger / J-Witex	
	Wire Rope Sheaves 100% Forged	Contractor to propose.	
	Wire Rope Rollers	Quay-Quip	Quay-Quip
	Personnel Elevator*	Alimak	Alimak
	Maintenance Hoist including the overhead traveling girders	SWF, Konecranes, Morris, ZPMC	
	MV Cable Reeling System *	Stemmann, Cavotec, Wampfler	Stemmann
	MV Trailing Cable	Prysmian, Tratos	Prysmian
	Trolley Energy Cable Chain	IGUS P4	IGUS P4
	Trolley Energy Cable Chain Cables	IGUS	IGUS
	Spreader feed cable reeling system *	Same as MV cable reel system	
	Spreader Feed Cable	Prysmian, Tratos	Prysmian
	Spreader Cable Plug/Socket	Harting, ODU according to existing spreader type	Harting, ODU according to existing spreader type
	Electrical Cables – Drive Motors	Fujikura, Hitachi, Belden, Olflex, Lapp (2YSLCY-J or similar)	Jin Feng
	Electrical Cables – Fixed & Flexible	Fujikura, Hitachi, Belden, Olflex, Lapp (H07RN-F or similar)	Jin Feng
	Operator's Cabin *	Merford Ergo Cabin	METAGRO Ergo Cabin
	Driver's Seat & Consoles *	Merford Ergo Seat	METAGRO Ergo Seat
	Master Controller	Spohn & Burkhardt, Gessmann	Spohn & Burkhardt, Gessmann
	Air Conditioning Units	York, Carrier, Panasonic, Daikin	York, Carrier, Daikin
	LED Floodlights	Philips, Nanhua	
	LED Walkway lights	Philips, Nanhua, Bals	
	Communications	Gaitronics	Gaitronics
	Overload Protection & Alarm	Hirschmann (PAT), Brosa, Tecsis, Titze	.
	Anemometer	Vaisala	Vaisala
	LED Aviation Light	Nanhua	Nanhua
	Gantry Warning Alarm/Light	Nanhua, Brigade	Nanhua
	Drum Encoders (Main-Hoist, Trolley and Boom-Hoist)	Hubner Giessen U-One	Hubner Giessen U-One
	Limit Switches (Small)	Telemecanique, Schmersal	Telemecanique

Item No.	Description of Stipulated Component	Stipulated Suppliers for Item	Tenderer's Preferred Supplier Chosen from Stipulated Suppliers
	Limit Switches (Large)	Schmersal	Schmersal
	Gravity Limit Switch	Joslyn Clark, Matsushima (CHL22 or Equivalent)	Matsushima
	Magnet operated Limit Switches	Schmersal	Schmersal
	Proximity Switches	Turck, IFM	Turck
	Photoelectric Switch	Sick, Banner	Banner
	Vessel Profiling Scanners	Sick, Lase	Sick, Lase
	Gantry anti-collision	Cathay Nebula	Cathay Nebula
	Fire Suppression System for E-rooms	Kidde	Kidde
	Cabin Access and Gate Interlock	Fortress	Fortress
	Operator Aid and Boom Latch Camera and Monitor	Orlaco	Orlaco
	Ship Profile System (SPS)	Cathay Nebula	Cathay Nebula
	Chassis Positioning System (CPS)	Cathay Nebula	Cathay Nebula
	CCMS & Remote CMS	By electrical system integrator	

2. Crane Livery, Purchaser's Logo, Asset Numbers

The following table shall be read in conjunction with Clause 6.4 (Crane Livery, Purchaser's Logo, Asset Numbers,Signs).

	ITEM	Location	PAINT COLOR
	Main Steel Structure		Traffic Orange RAL 2009
	Operator's Cabin	Exterior	Traffic White RAL 9016
	Checker's Cabin	Exterior	
	Machinery House	Exterior & Interior	
	Operator's Cabin	Interior & Floor	Traffic Grey A RAL 7042
	Checker's Cabin	Interior & Floor	
	Machinery House	Floor	
	Trolley		Traffic Yellow RAL 1023
	Spreader	Excluding Flippers	
	Head-block		
	Stairways, Ladders, Platforms & Handrails	Treads of stairways and grids of platforms shall be left in galvanized condition	
	Buffers	Trolley and Gantry End of Travel	
	Guards	Around machinery, wheels, couplings etc.	
	Container Top Safety Frame		
	Hook Beam	(if applicable)	
	Test Weight	(if applicable)	
	Spreader Trailer	(if applicable)	
	Flippers on Spreader	With colour coded paddles	Traffic Red RAL 3020
	Junction boxes	Stainless steel, protected by a translucent protection layer (film or lacquer)	None
	Cable runways – external	Cable trays/covers, cable ladders, conduits	Same colour as the surrounding structure or the structure they are mounted to
	Major component – external	Reducers, motors, hydraulic power packs and cylinders	
	Major component – internal	Reducers, motors, hydraulic components	Original equipment manufacturers' colour
	Other components – internal and external	Brakes, limit switches, lights, etc.	
	Company Logo	Mounted on the sides of the M-house	As per logo definitions
		TBD	
	Crane designations	Numbers will be attached to the equipment	TBD
	Spreader designations	Including spare spreader	TBD
	Cargo beam designations		TBD

	ITEM Location	PAINT COLOR
	CTSF designations	TBD
	Test Weight designations	TBD

3. Tools List

The following table shall be read in conjunction with Clause 6.8.1 (Maintenance Tools).

	ITEM	QUANTITY	COMMENT
	Mechanical Maintenance Tools		
	Stainless steel wear gauges for: ■ Each of the sheave grooves ■ Trolley and gantry wheels ■ Each of the wire rope winch drum grooves	1 (one) set per crane	Each wear gauge shall be clearly marked with the component name to be gauged.
	Hydraulic Maintenance Tools		
	Digital manometer complete with remote tubes and adaptors for each of the hydraulic	2 (two) set per crane	
	Long access Allen keys to adjust hydraulic pumps, fit solenoids and maintain other hydraulic components	2 (two) set per crane	
	Electrical / Electronic Maintenance Tools		
	Siemens M4 Premium PG laptop computer preloaded with all software necessary to interface with PLC's, Drives, CCMS, Spreader and/or other devices requiring program reload, data download or fault diagnostic tracing with external computer.	1 (one) set per contract	Laptop computers provided shall be fit for purpose for the rugged environment in which they are to be used. Laptop specifications to be reviewed and approved by the Purchaser.
	Interface components such as cables, converters or plugs and sockets necessary to connect the PG shall be supplied.	2 (two) set per laptop computer	
	Original software to operate the computer or communicate with devices, along with any instructions for use.	1 (one) set per laptop computer	The operating license shall be assigned to the Purchaser.
	Autem Pro 5 PLC analyser software installed on Field laptops	1 (one) set per laptop computer	
	Multi-meter – Fluke Type 289 to include frequency and max/min function fitted with "Fluke-289TPAK" and "Fluke C781 Carrying Case" accessories, with electronic test probe sets "Fluke TL 90".	2 (two) set per contract	
	Oscilloscope – Fluke Type 190 -204 series II fitted with "Fluke VPS410 Kit".	1 (one) set per contract	
	Clamp Ammeters – Fluke Type i1010 to include AC, DC, Voltage and Current	2 (two) set per contract	
	Fibre Optic cleaning and testing kit such as Kingfisher KI2000 or SimpliFibre® Pro Optical Power Meter and Fibre Test Kit	1 (one) set per contract	
	Profibus analyzer such as Procentec ProfiTrace Ultra Plus	1 (one) set per contract	

	ITEM	QUANTITY	COMMENT
	Insulated Electrical Tool sets (VDE Type) including: ■ Screwdrivers ■ Side Cutters ■ Combination Pliers	2 (two) set per crane	
	Lux Lighting measurement meters	2 (two) set per contract	
	Noise Meters	2 (two) set per contract	
	Vibration Measurement Meters	2 (two) set per contract	
	Infra-Red Thermal Imaging Tool Fluke Type FLK-Ti25 9 Hz	1 (one) set per contract	
	Insulation Resistance Testing Meter – Fluke Type 1555 with 10KV Insulation Tester Kit "Fluke-1555".	1 (one) set per contract	
	High Quality Ratchet Crimp Tool Set for RYB crimps and bootlace ferrules	2 (two) set per contract	
	Gas soldering iron	2 (two) set per contract	
	Tachometers	2 (two) set per contract	
	Laser Alignment system such as SKF TKSA 80	1 (one) set per contract	
	Very Low Frequency (VLF) test equipment from non-Chinese manufacturer.	1 (one) set per contract	
	Label printing machine and 3M tapes for replacement of labels	1 (one) set per contract	

4. Documentation Status Control Sheets

Item	Description	Due / Actual Dates	Comments
	Submittal of Project Documents		
	Project Organization Chart (Shop & Site) → 7.1.2	2 weeks after contract award	
	Project Schedule / Programme (Shop & Site) → 7.1.3	2 weeks after contract award	
	Project Progress Report → 7.1.4	Monthly until taking-over of last crane(s)	
	Ordered Spare Parts List → 7.1.8	3 months after contract award	
	Training Program → 7.1.9	3 months before arrival of first crane(s)	
	Submittal of Conceptual Design Drawings	1 month after contract award	PDF-files, plotted in original document size, black & white
	Drawing Management System details → 7.2.1		
	Crane General Arrangement with overall/main dimensions and speeds of operation		
	Trolley General Arrangement		
	Head-block General Arrangement		
	Head-block Twist Lock Assembly		
	Spreader General Arrangement		
	Spreader Twist Locks Assembly		
	Gantry Trucks & Equalizers General Arrangement		
	Machinery House General Arrangement		
	Operator's Cab General Arrangement		
	Control Consoles & Chair Layout in the cab		
	Operator Visibility Diagram		
	Tie Down Equipment (Gantry, Trolley)		
	Wheel Clamp Arrangement		
	Boom Hinge and Support Details		
	Wire Rope Support for Stowed Boom		
	Boom Latch Locking Device		
	Trolley Rail and Transition at Girder / Boom		
	Walkways, Stairs & Platforms (Layouts and Details)		
	Rope Reeving Diagram with Rope End Fixing Details		

Item	Description	Due / Actual Dates	Comments
	Main Hoist Drive Arrangement		
	Trolley Drive Unit Arrangement		
	Boom Hoist Drive Unit Arrangement		
	Gantry Drive Arrangement		
	Trimming Device Arrangement		
	Listing Device Arrangement		
	Skewing Device Arrangement		
	Wheels (Gantry and Trolley) Detail		
	Sheaves Detail with material, treatment and profile		
	Emergency Motors Calculations		
	Maintenance Hoist Detail and General Arrangement		
	Personnel Elevator Arrangement and Access Details		
	Checker's Cab General Arrangement		
	Electrical One Line Diagram		
	Typical electric details such as support of boxes, lights, and conduit/tray arrangements/segregation		
	Crane Livery, Purchaser's Logo, Asset Numbers, Signs drawings → 6.4		
	Submittal of Calculations and Data	1 month after contract award	PDF-files, plotted in original document size
	Stability Calculations (including Dynamic Snag Load Condition)		
	Wheel Loads and Typhoon Tie down Loads Calculations including wind load analysis		
	Stress Calculation for Critical Areas of Structure		
	Fatigue Analysis for Crane Structure		
	Design calculations for the hoist, trolley, gantry, and boom hoist main motion component parts		
	Gearbox sizing calculation		
	Brake sizing calculation with approval from the brake supplier		
	Drive motor sizing calculation		
	Manufacturer motor data sheets for selected application		
	Converter and Motor Module sizing calculations with approval from drive system supplier		
	Main Hoist Load/Speed Curve		
	Trim list, skew and snag component sizing and selection		

Item	Description	Due / Actual Dates	Comments
	Hydraulic system component sizing calculation		
	Gantry Buffer Load Calculations (Boom Lowered and Boom Stowed)		
	Trolley Buffer Load Calculations		
	Rail Clamp Capacity Calculations		
	Gantry Braking Capacity and Braking Distance Calculations (under various wind load conditions up to braking limit)		
	Wire Rope Fleet Angle Calculations		
	Electrical load calculations inclusive Peak Power Consumption and voltage drop over crane supply cables		
	MV switchgear data sheets		
	Transformer sizing calculations and transformer data sheet		
	Harmonics and Power Factor Calculations		
	Electrical room(s) cooling and heating calculation		
	Lighting calculations		
	Noise calculations		
	Review of Conceptual Design Drawings, Calculations and Data	2 weeks after receipt of concept. design	Marked-up PDF-files
	Review of Conceptual Design Drawings		
	Review of Calculations and Data		
	First Design Review Meeting	Following review of conceptual design	At Contractor's design office
	Submittal of Detailed Design Drawings, Calculations and Data	1 month after first design review meeting	PDF-files, plotted in original document size
	All revised design documents as required during the first design review meeting		
	All remaining main structure general and detailed drawings		
	All remaining mechanical general and detailed drawings		
	Power Cable Reel and Slip Ring data sheets		
	Power Cable Specification and Sectional Dimension Drawing		
	Trolley Cable Chain specification		
	Spreader cable reel system and spreader cable data sheets		

Item	Description	Due / Actual Dates	Comments
	Electrical Circuit Diagrams		
	Crane control interlocking and safety function description		
	Communication system drawings and data sheets		
	CCMS/RCMS system drawings and function description		
	Control Panels/Operation Stations General Arrangement		
	Switchgear General Arrangement		
	Cooling system design and Air Conditioners data sheets		
	Cable laying detailed drawings and description		
	All other structural, mechanical and electrical general and detailed drawings as requested by the Engineer.		
	All other structural, mechanical, and electrical calculations as requested by the Engineer		
	Review of Detailed Design Drawings, Calculations and Data	2 weeks after receipt of detailed design	Marked-up PDF-files
	Review of Detailed Design Documents		
	Second Design Review Meeting	Following the review of detailed design	At Contractor's design office
	Submittal of Final Design Drawings, Calculations and Data (=Design freeze)	2 weeks after second design review meeting	PDF-files, plotted in original document size
	All revised design documents as required during the second design review meeting		
	All other structural, mechanical and electrical general and detailed drawings as requested by the Engineer.		
	All other structural, mechanical, and electrical calculations as requested by the Engineer		
	Quality Assurance Inspection and Test Protocols		
	Quality Assurance Program / Manuals → 7.3.1	1 month after contract award	PDF-file
	Pre-Shipment Inspection and Test on Completion Protocol → 7.3.3	4 months before shipment of the first crane(s)	PDF-file
	Complete set of the Contractor's QC documentation of the crane(s)	Before loading on to the vessel	PDF-file (scanned copy of original documents)

Item	Description	Due / Actual Dates	Comments
	Static wheel load verification / Weight reports → 7.5.2(6)	Before loading on to the vessel	PDF-file (scanned copy of original document)
	Completed Pre-Shipment Inspection Protocol (of each crane)	Before loading on to the vessel	PDF-file (scanned copy of original document)
	Completed Pre-Shipment Inspection and Test on Completion Protocol (of each crane)	1 month after taking-over of each crane	Original protocol and PDF-file (scanned copy of original document)
	Submittal of Crane Shipment and Site Activity Documents	3 months before arrival of first crane(s)	
	Crane Delivery Method Statement → 7.1.5		
	Site Work Method Statement → 7.1.6		
	Daily Plan and Report (Site) → 7.1.7	Daily (upon Site activities commenced)	
	Voyage route, Sea-state loads, design waves, accelerations, vessel sailing schedule, justification for criteria (DNV)		
	Crane transportation Stability Calculations including corner loads and led loads for the design criteria		
	Sea fastening calculations including allowable stress, safety factors		
	Off-Loading Calculations including dock structural stress analysis, jacking loads, rolling/skidding loads		
	All loading, shipping, sea-fastening, and unloading drawings (arrangements and details)		
	Submittal of Operation and Maintenance Instructions		
	Preliminary Operation Manuals (English) → 7.4.1	3 months before arrival of first crane(s)	3 sets hardcopy and 2 sets CD-ROM
	Preliminary Operation Manuals (local language) → 7.4.1	3 months before arrival of first crane(s)	3 sets hardcopy and 2 sets CD-ROM
	Final Operation Manuals (English) → 7.4.1	1 month after Taking-over of the first crane(s)	5 sets hardcopy and 2 sets CD-ROM
	Final Operation Manuals (local language) → 7.4.1	1 month after Taking-over of the first crane(s)	5 sets hardcopy and 2 sets CD-ROM

Item	Description	Due / Actual Dates	Comments
	Preliminary Maintenance Manuals (English) → 7.4.2	3 months before arrival of first crane(s)	3 sets hardcopy and 2 sets CD-ROM
	Preliminary Maintenance Manuals (local language) → 7.4.2	3 months before arrival of first crane(s)	3 sets hardcopy and 2 sets CD-ROM
	Final Maintenance Manuals (English) → 7.4.2	1 month after Taking-over of the first crane(s)	5 sets hardcopy and 2 sets CD-ROM
	Final Maintenance Manuals (local language) → 7.4.2	1 month after Taking-over of the first crane(s)	5 sets hardcopy and 2 sets CD-ROM
	Operationally Critical Components with inspection and replacement schedule → 2.11	1 month after Taking-over of the first crane(s)	PDF-files, plotted in original document size
	Lubricant List → 7.4.3	3 months after contract award	PDF-files, plotted in original document size
	Structural Maintenance Program → 7.4.4	3 months before arrival of first crane(s)	PDF-files, plotted in original document size
	Submittal of As-built Design Documents	1 month after Taking-over of the first crane(s)	
	As-built structural, mechanical and electrical drawings		
	Detailed drawings for wearing parts		
	Control logic programs and parameter settings		
	Full details of all bought-in equipment, drawings, instructions, etc.		
	List and specification of structural connection bolts and machinery fitting bolts with tightening torque value for each location/size.		

1. Inspection / Test Control Sheets

The following six sheets provide a guide to the minimum inspection, test, reports and certifications which arerequired by the Purchaser.

Codes depicted in the Inspection / Test Control Sheets are defined as follows:

By the Contractor

M	=	Mill Certificate to be submitted
R	=	Inspection Report to be submitted
T	=	Test Report to be submitted

By the Purchaser, Engineer or Engineer's Representative

C1	=	Certificates or reports to be produced
W1	=	Inspection / Test to be witnessed for 100% of the Works
W3	=	Inspection / Test to be witnessed at random for 5% - 20% of the Works

Quayside Crane
Inspection Sheet (1 of 7)

I) Main Structure	Chemical Properties	Mechanical Properties	Welding Process and Welder Qualifications	Edge Preparation check & Visual Inspection of Welds	Non-Destructive Test	Hardness	Visual Inspection and Weather Protection Check	Dimensional Check	Proof Load Test	Braking Test	Function or Heat Run Test	Dielectric Test	Insulation Test	Characteristics Test	Painting	Weighing	Load Test (Note)	Deflection Measurement	Inventory	Preparation work for Ship/Pack
Portal Frame (Sill beam, Legs, Portal Tie, Diagonal Beam and Girder Support Beam	M	M			M			R												
	C1	C1	C1	W 3	C1		W 1	W 3							W 3					
Trolley Girder	M	M			M			R												
	C1	C1	C1	W 3	C1		W 1	W 3							W 3					
A - Frame	M	M			M			R												
	C1	C1	C1	W 3	C1		W 1	W 3							W 3					
Boom	M	M			M			R												
	C1	C1	C1	W 3	C1		W 1	W 3							W 3					
Back Stay & Forestay	M	M			M			R												
	C1	C1	C1	W 3	C1		W 1	W 3							W 3					
Bogie & Equalizer Beam	M	M			M			R												
	C1	C1	C1	W 3	C1		W 1	W 3							W 3					
Trolley Frame	M	M			M			R												
	C1	C1	C1	W 3	C1		W 1	W 3							W 3					
Machinery House &								R												

Machinery House Fittings							W1	W3							W3					
Typhoon Tie Down Gear (If applicable)	M	M			M			R	T											
	C1	C1	C1	W3	C1		W1	W3	W1						W3				W1	W1
Spreader Frame and Headblock Frame	M	M			M			R												
	C1	C1	C1	W3	C1		W1	W3							W3					

Note:

Quayside Crane
Inspection Sheet (2 of 7)

II) Machinery Equipment	Chemical Properties	Mechanical Properties	Welding Process and Welder Qualifications	Edge Preparation check & Visual Inspection of Welds	Non-Destructive Test	Hardness	Visual Inspection and Weather Protection Check	Dimensional Check	Proof Load Test	Breaking Test	Function or Heat Run Test	Dielectric Test	Insulation Test	Characteristics Test	Painting	Weighing	Load Test (Note)	Deflection Measurement	Inventory	Preparation work for Ship/Pack
Rope Drum	M	M			M			R												
	C1	C1	C1	W3	C1		W1	W3												
Pinion & Gear	M	M			M	T		R												
	C1	C1			C1	C1	W1	W3												
Rope Sheave	M	M				T		R												
	C1	C1				W3	W1	W3												
Wheels (Gantry & Trolley)	M	M				T		R												
	C1	C1				W3	W1	W3												
Reducer	M	M																		

	C1	C1	C1	W 3		W 1	W 1	W 1			W 1									
								C1			C1									
Wire Rope (Main Hoist, Boom Hoist & Trolley)	M	M						R	T	T										
	C1	C1					W 1	C1		C1										
Hydraulic Unit (Spreader, Rail Clamp, Boom Latch, Rope Tensioner & Antisway)								R			T									
							W 1	W 3			C1									
Twistlocks (Headblock & Spreader)	M	M			M			R	T											
	C1	C1			C1		W 1	W 3	W 3											
Hook	M	M			M			R	T											
	C1	C1			C1		W 1	W 1	W 3							W 3				

Note:

Quayside Crane
Inspection Sheet (3 of 7)

III) Devices Subassembly (Sheet 1 of 2)	Chemical Properties	Mechanical Properties	Welding Procesand Welder Qualifications	Edge Preparation check & Visual Inspection of Welds	Non-Destructive Test	Hardness	Visual Inspection and Weather Protection Check	Dimensional Check	Proof Load Test	Breaking Test	Function or Heat Run Test	Dielectric Test	Insulation Test	Characteristics Test	Painting	Weighing	Load Test (Note)	Deflection Measurement	Inventory	Preparation work for Ship/Pack
Gantry Drives								R			T									
							W 1	W 3			W 3				W 3					
Cable Reel								R			T									

							W 1	W 3			W 3				W 3							
Rail Clamp and Stowage Pin								R			T											
							W 1	W 3			W 3				W 3							
Main Hoist Drive								R			T											
							W 1	W 3			W 3				W 3							
Head Block								R			T					T						
							W 1	W 3			W 3				W 3	W 1	W 1					
Anti-sway Device (NOT APPLICABLE THIS CONTRACT)								R			T											
							W 1	W 3			W 3				W 3							
Separate Trolley Drive								R			T											
							W 1	W 3			W 3				W 3							
Trim / List / Skew Device								R			T											
							W 1	W 3			W 3				W 3							
Boom Hoist Drive including Emergency Brake								R			T											
							W 1	W 3			W 3											
Boom Latch & Lock Device								R			T											
							W 1	W 3			W 3				W 3							

Note:

Quayside Crane
Inspection Sheet (4 of 7)

III) Devices Subassembly (Sheet 2 of 2)	Chemical Properties	Mechanical Properties	Welding Process and Welder Qualifications	Edge Preparation check & Visual Inspection of Welds	Non-Destructive Test	Hardness	Visual Inspection and Weather Protection Check	Dimensional Check	Proof Load Test	Braking Test	Function or Heat Run Test	Electric Test	Insulation Test	Characteristics Test	Painting	Weighing	Load Test (Note)	Deflection Measurement	Inventory	Preparation work for Ship/Pack
Trolley Drive								R			T						(T)			
							W1	W3			W1									
Festoon Cable Carriers								R												
							W1	W3			W1									
Trolley Rope Tensioner								R												
							W1	W3			W1						(T)			
Spreader								R			T					T	(T)			
							W1	W3			W1				W3	W1				
																	(W1)			
Heavy Lift Beam								R								T	(T)			
							W1	W3							W3	W1			W1	W1
																	(W1)			
Air Conditioner in Operators Cab & Machinery House								R			T									
							W1	C1			C1									
													T							
Operators Cab, Cab Fittings																				

and Control Stations							W 1	W 3						W 3				W 1	

Ventilation Fan in Machinery House											T									
							W 1				W 1									
													T							
Maintenance Hoist								R			T			T						
							W 1	W 3			C1			C1			(W 1)			
													T							
Trolley Assembly								R								T				
							W 1	W 3							W 3	W 1				W 1

Note: 1. Item in ( ) shall be carried out at Purchaser's Site.
2. Load Test includes Rated Load Test, Overload Test and Intermediate Load Test

Quayside Cranes
Inspection Sheet (5 of 7)

IV) Electrical Equipment	Chemical Properties	Mechanical Properties	Welding Process and Welder Qualifications	Edge Preparation check & Visual Inspection of Welds	Non-Destructive Test	Hardness	Visual Inspection and Weather Protection Check	Dimensional Check	Proof Load Test	Breaking Test	Function or Heat Run Test	Dielectric Test	Insulation Test	Characteristics Test	Painting	Weighing	Load Test (Note)	Deflection Measurement	Inventory	Preparation work for Ship/ Pack
HV Slip Ring								R				R			R					
							W 1	C1				C1			W 3					
												T	T							
HV Incoming Panel												R								
							W 1	C1			W 1	C1								
												T								
HV Distribution Panel								R				R								
							W 1	C1			W 1	C1								
												T*	T							
Transformer								R			R			R						

							W1	C1			C1	C1		C1	W3					
												T	T							
SCR Unit								R				R		R						
							W1	C1				C1	C1	C1						
													T							
AC Motor								R					R	R						
							W1	C1					C1	C1						
													T							
Magnetic Brake								R					R							
							W1	C1					C1							
													T							
Resistor								R					R	R						
							W1	C1					C1	C1						
													T							
Induction Motor								R			R		R	R						
							W1	C1			C1		C1	C1						
													T							
Control Panel								R					R							
							W1	C1					C1							
													T							

Note: * Fault Level Report shall be submitted

Quayside Crane
Inspection Sheet (6 of 7)

IV) Electrical Equipment (Cont'd)	Chemical Properties	Mechanical Properties	Welding Process and Welder Qualifications	Edge Preparation check & Visual Inspection of Welds	Non-Destructive Test	Hardness	Visual Inspection and Weather Protection Check	Dimensional Check	Proof Load Test	Breaking Test	Function or Heat Run Test	Dielectric Test	Insulation Test	Characteristics Test	Painting	Weighing	Load Test (Note)	Deflection Measurement	Inventory	Preparation work for Ship/Pack

Power Cable								R				R	(R)	R						
							W 1	C1				C1	T1	C1			T*			
													(W 1)							
Limit Switches													R							
							W 1	C1					C1		W 3					
Electrical Ground System																				
							W 1						W 1	W 1						

Note: 1. Item in ( ) shall be carried out at Purchaser's Site.

Quayside Crane
Inspection Sheet (7 of 7)

V) Total Crane Assembly, Spare Parts, Accessories and Manuals	Chemical Properties	Mechanical Properties	Welding Process and Welder Qualifications	Edge Preparation check & Visual Inspection of Welds	Non-Destructive Test	Hardness	Visual Inspection and Weather Protection Check	Dimensional Check	Proof Load Test	Braking Test	Function or Heat Run Test	Electric Test	Insulation Test	Characteristics Test	Painting	Weighing	Load Test (Note)	Deflection Measurement	Inventory	Preparation work for Ship/ Pack
Air Compressor											(T)									
Crane Assembly											T		T	(T)			(T)	(T)		
							W1	W3			W1		C1		W3					W1
							(W1)	(W1)			(W3)		(W1)	(W1)	(W1)		(W1)	(W1)		
Spare Parts																				
							W1								W3				W1	W1
							(W1)												(W1)	
Accessories Wear Gauges																				
							W1								W3				W1	W1
							(W1)												(W1)	
Ro-Ro Method Statement & Program																				
																			W1	
Operating Instructions																				
																			W1	
Maintenance Manual																				
																			W1	

Oil & Lubricant List																				
																			W 1	

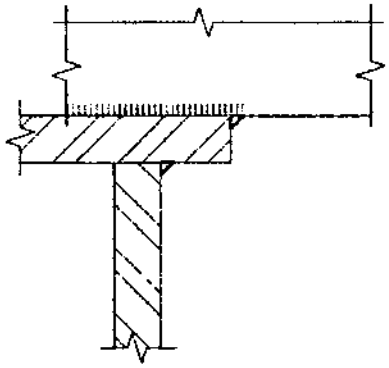
Note:
1. Item in ( ) shall be carried out at Owners Site
2. Load Test includes rated load test, overload test and intermediate load test.
3. The vertical deflection of the boom and the girder shall be measured or rated load and overload. Horizontal deflection of the boom shall be measured with rated load. Both vertical and horizontal measurement of trolley rails and girder and boom straightness at no load shall be recorded.

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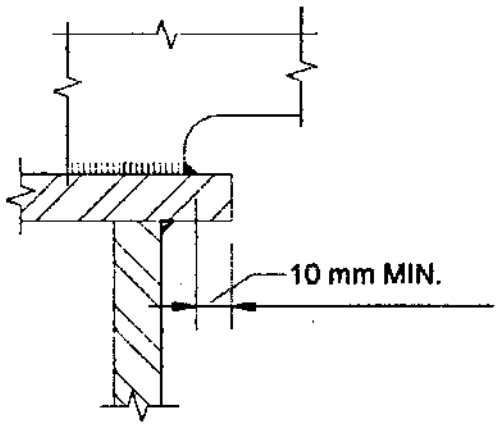
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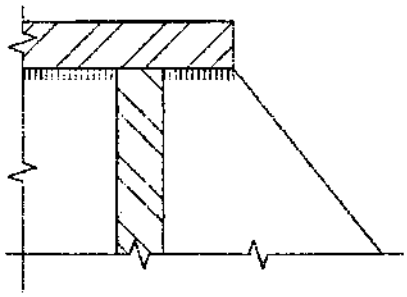
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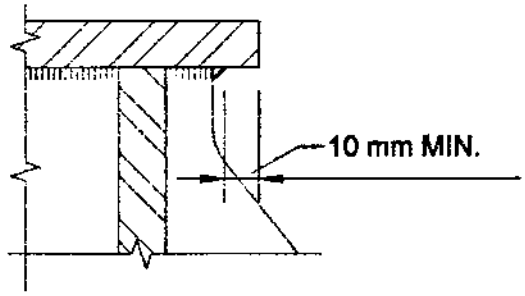
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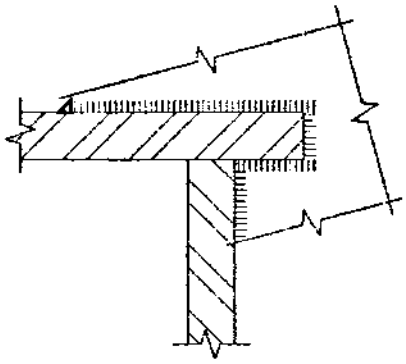
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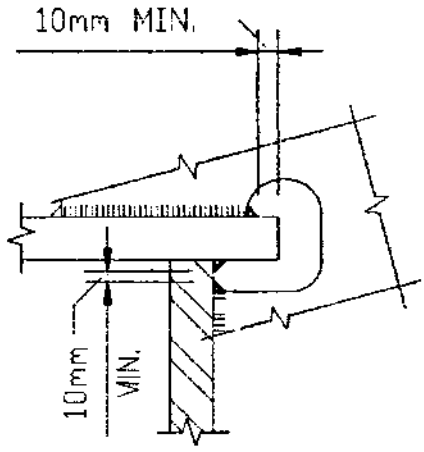
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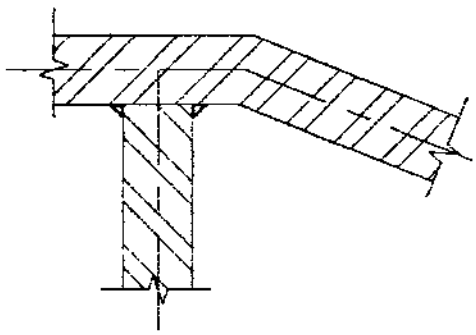
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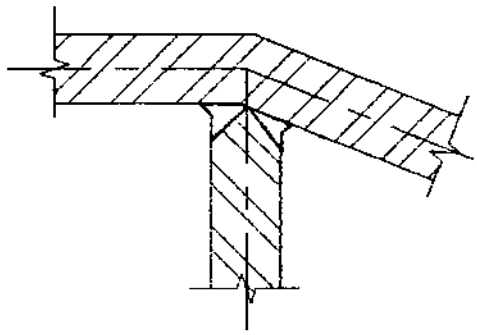
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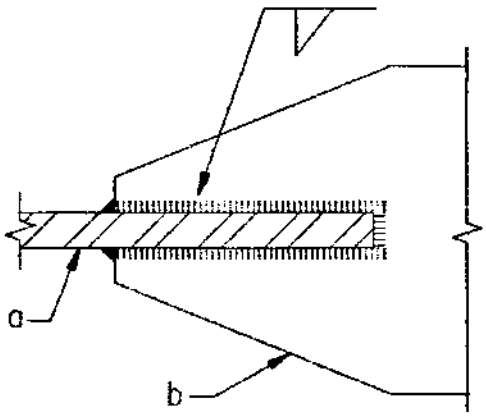


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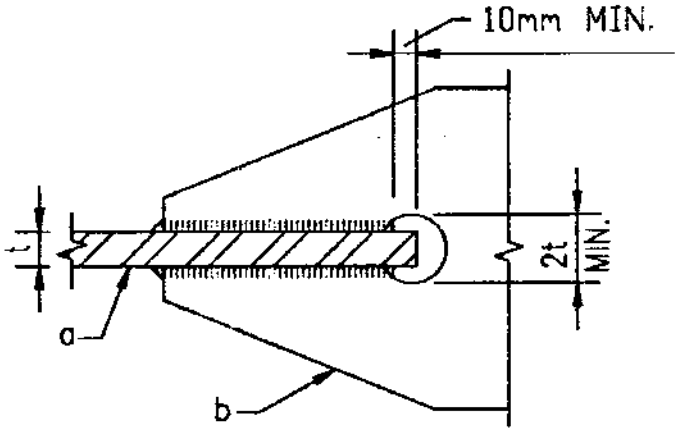
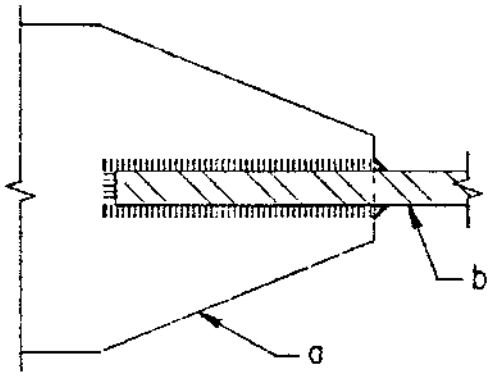
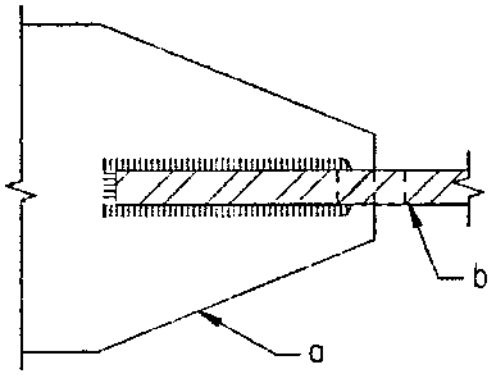


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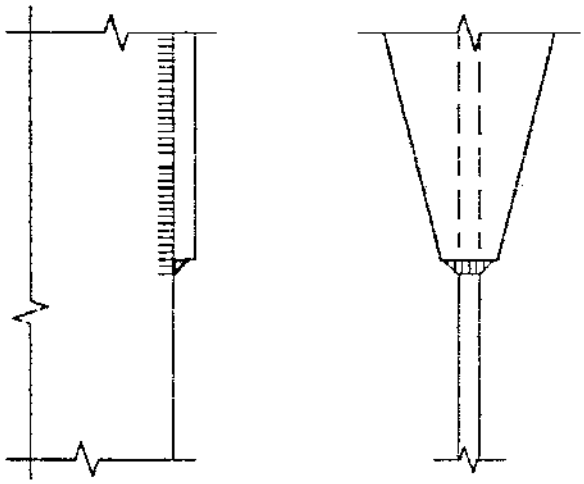
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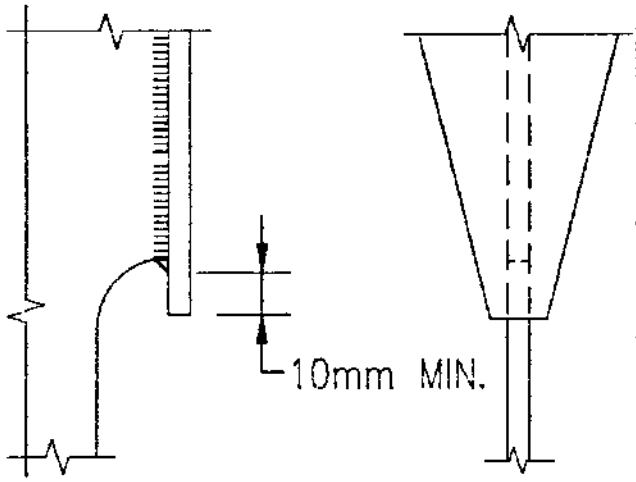
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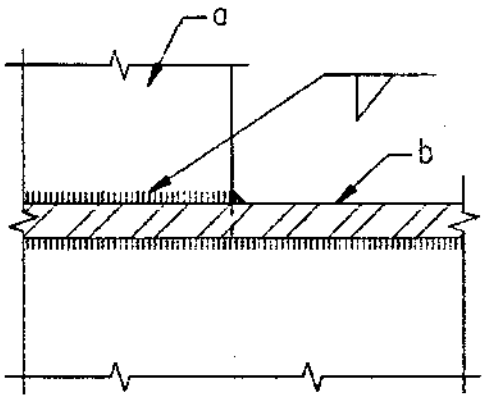


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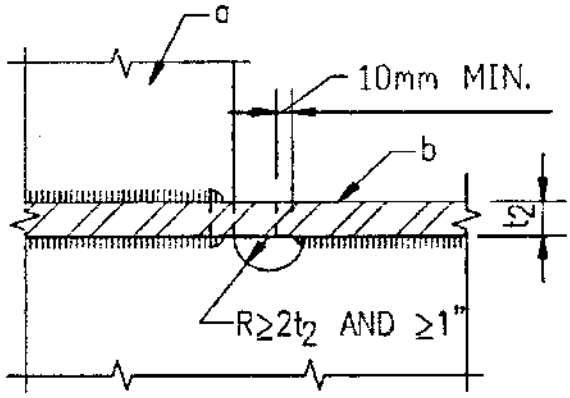
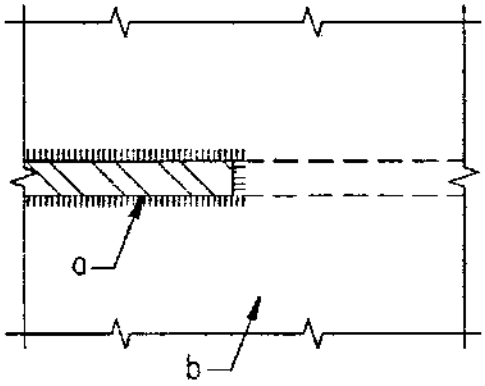
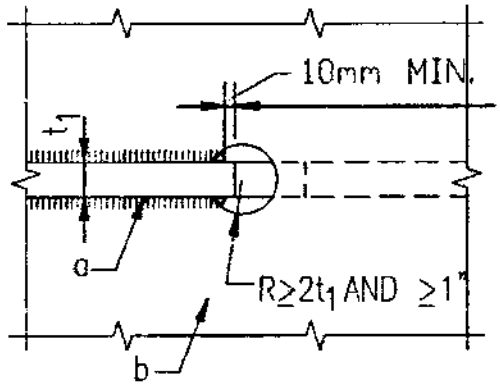


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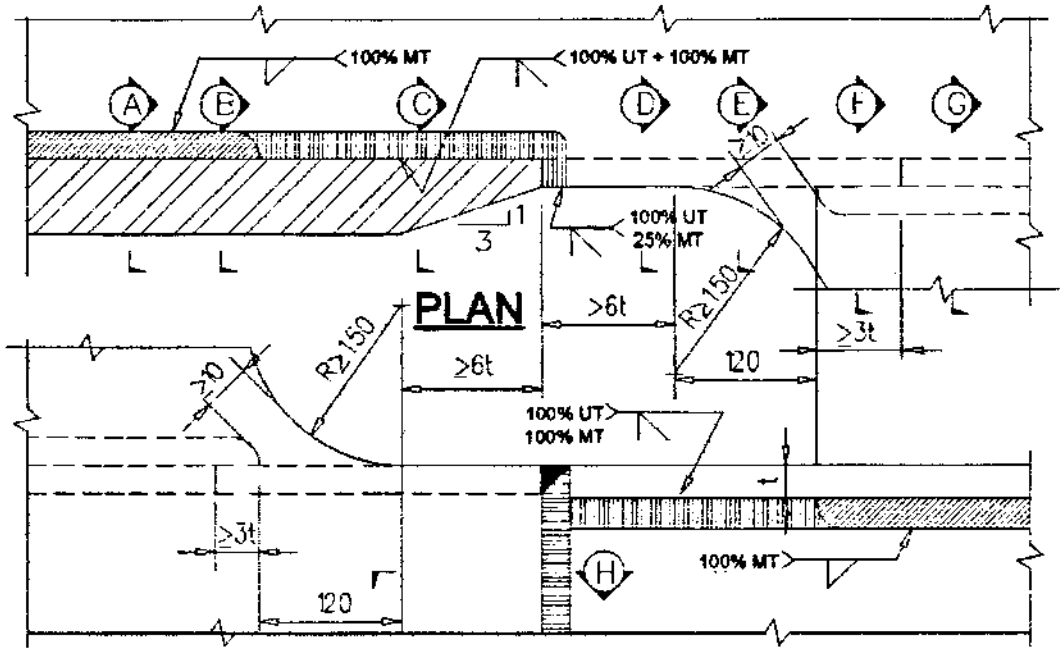
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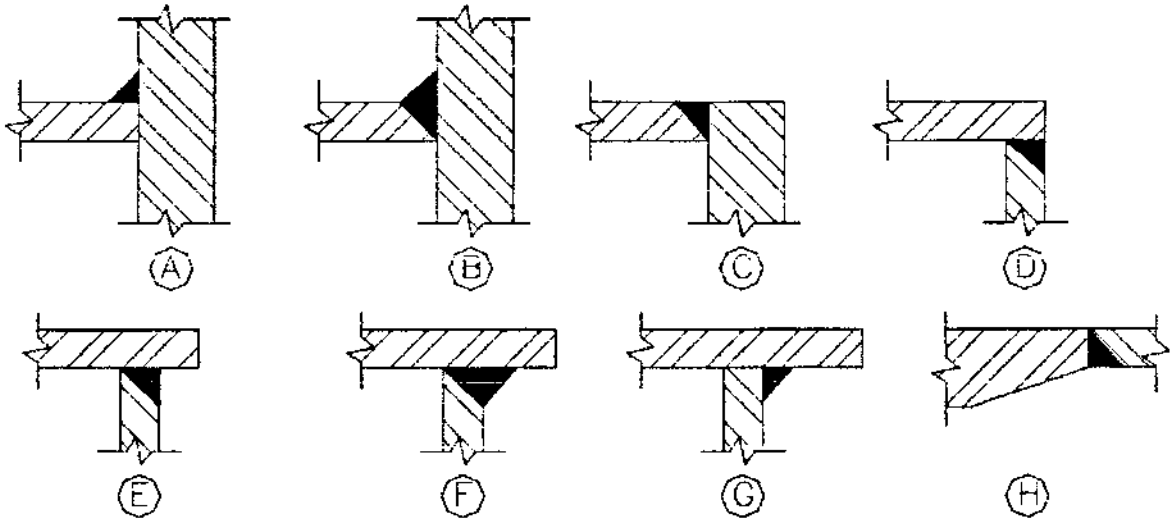
Structural Details

Avoidance of Wraparound Weld Acceptable

See Sht. 7 for isometric view.



ELEVATION



Note: Welds shall conform to the most recent edition of AWS D1.1, including the requirements for cyclically loaded structures.

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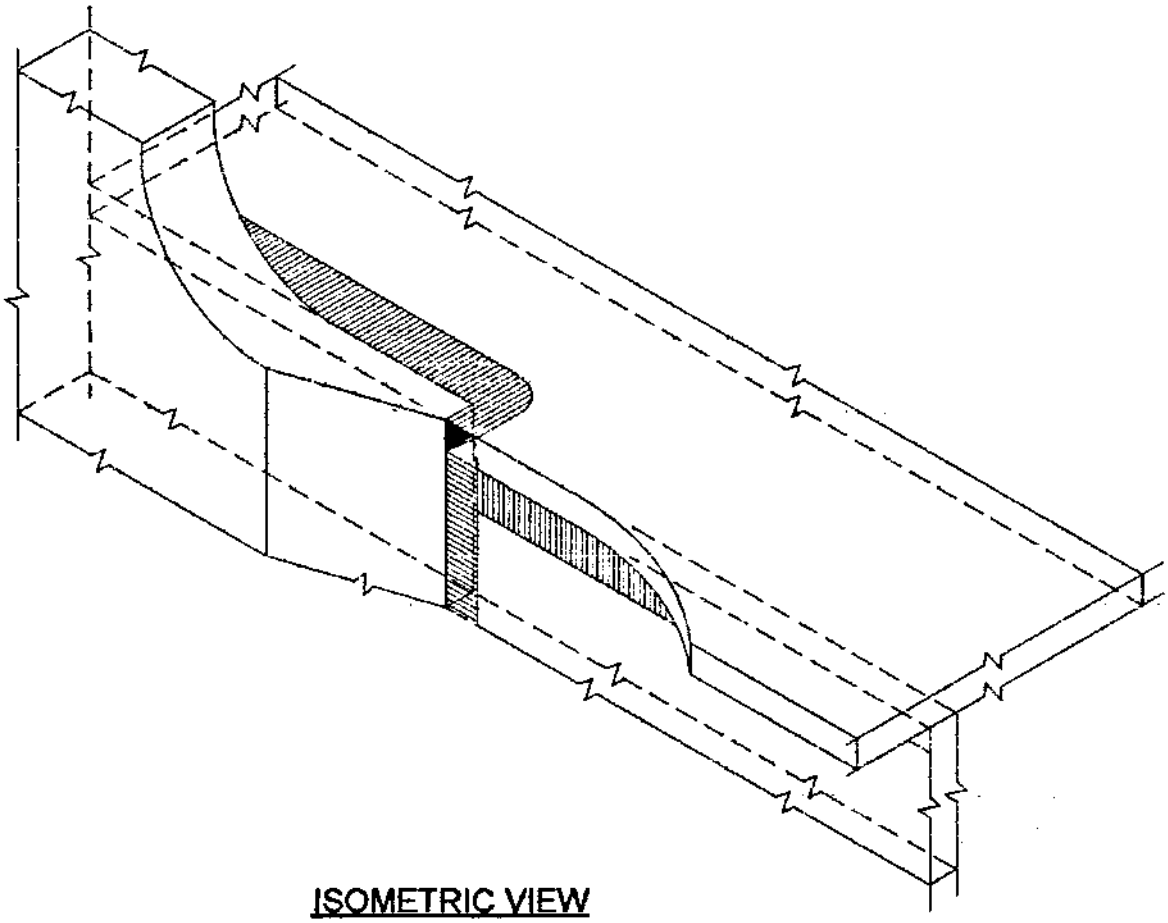
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Structural Details

Continued from Sht. 6.

Avoidance of Wraparound Weld Acceptable



ISOMETRIC VIEW

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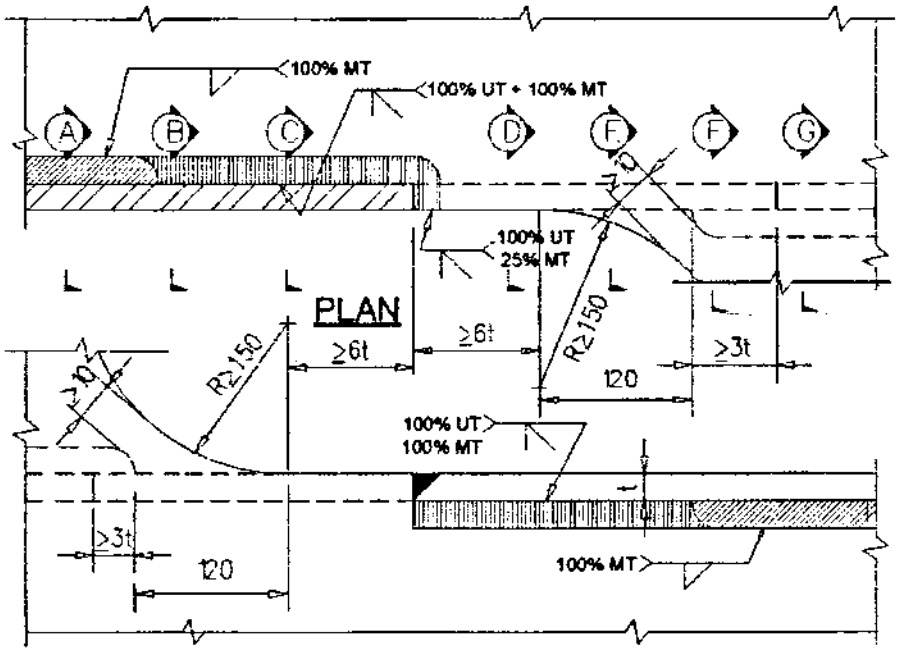
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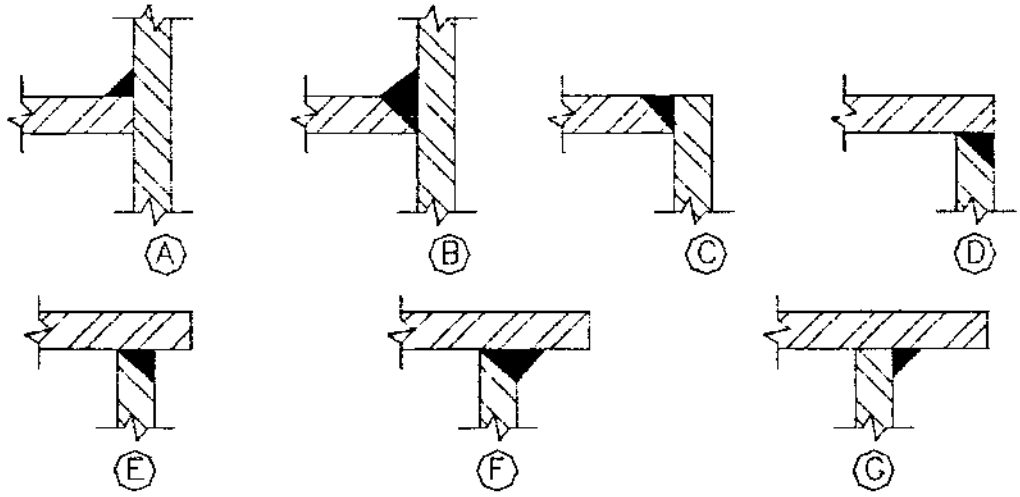
Structural Details

See Sht. 9 for Isometric View

Avoidance of Wraparound Weld Acceptable



ELEVATION



Note: Welds shall conform to the most recent edition of AWS D1.1, including the requirements for cyclically loaded structures.

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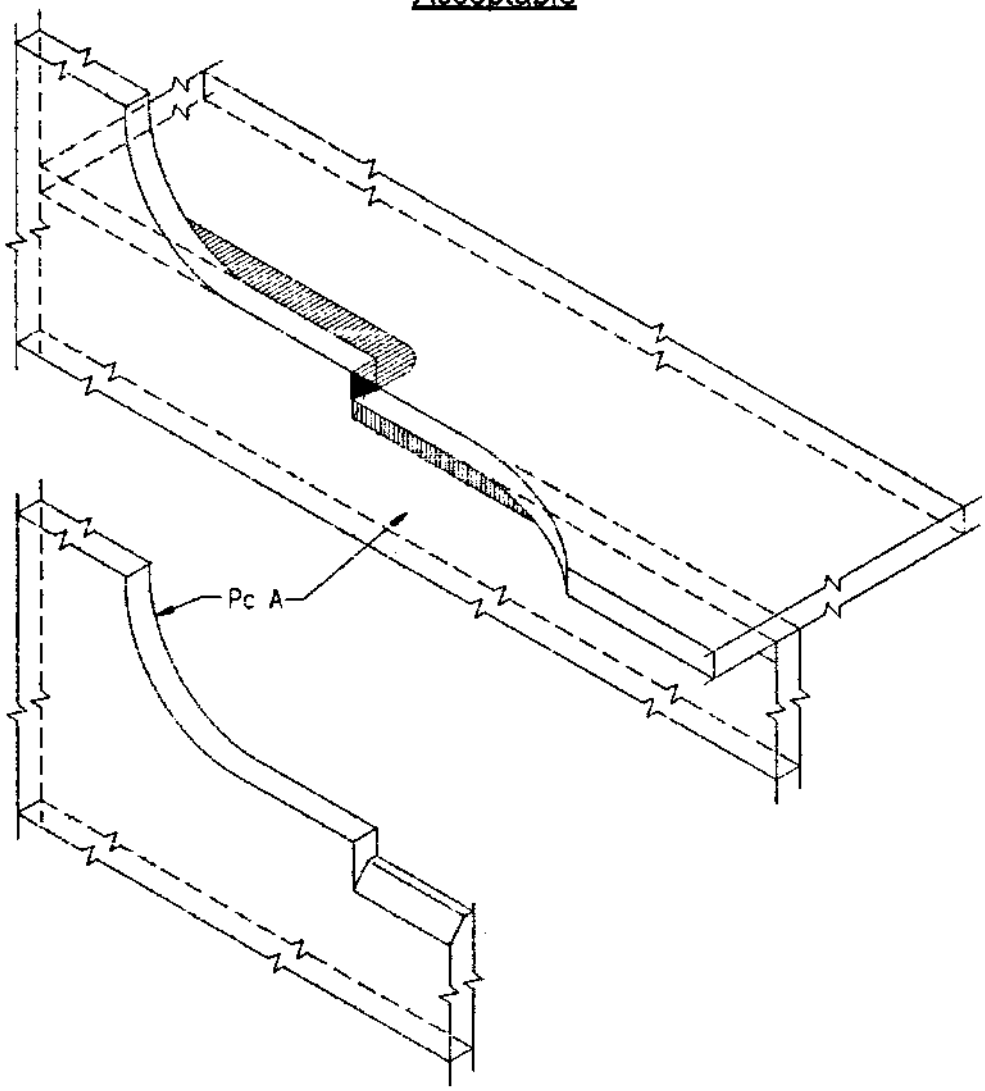
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Structural Details

Continued from Sht. 8.

Avoidance of Wraparound Weld Acceptable



ISOMETRIC VIEW

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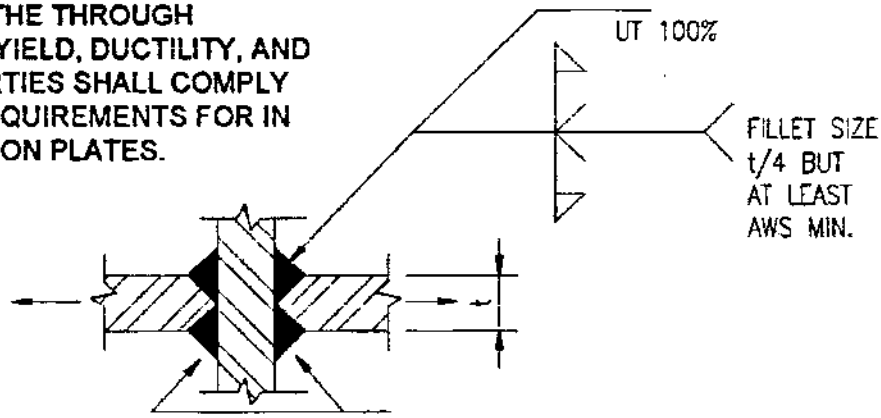
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Structural Details

Cruciform Weld

FOR COMPONENTS
CARRYING CALCULATED
AXIAL STRESS

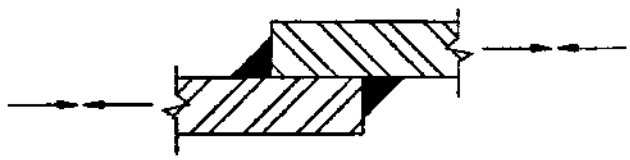
FOR FCMS: THE THROUGH THICKNESS, YIELD, DUCTILITY, AND CVN PROPERTIES SHALL COMPLY WITH THE REQUIREMENTS FOR IN PLANE TENSION PLATES.



U.T. TO CHECK FOR LAMELLAR TEARS BEFORE WELDING AND 36 HOURS AFTER WELDING.

Eccentric Lap Joints

ECCENTRIC LAP JOINTS
BOLTED OR WELDED
ARE NOT ACCEPTABLE
ON COMPONENTS CARRYING
CALCULATED AXIAL STRESS.

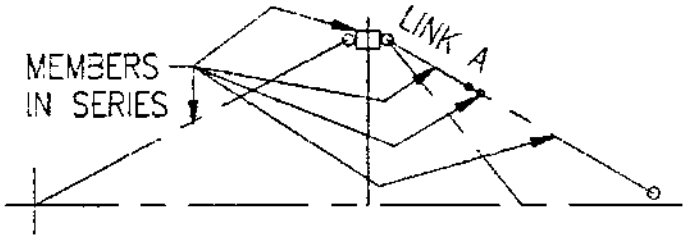


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Structural Details
Members in Series

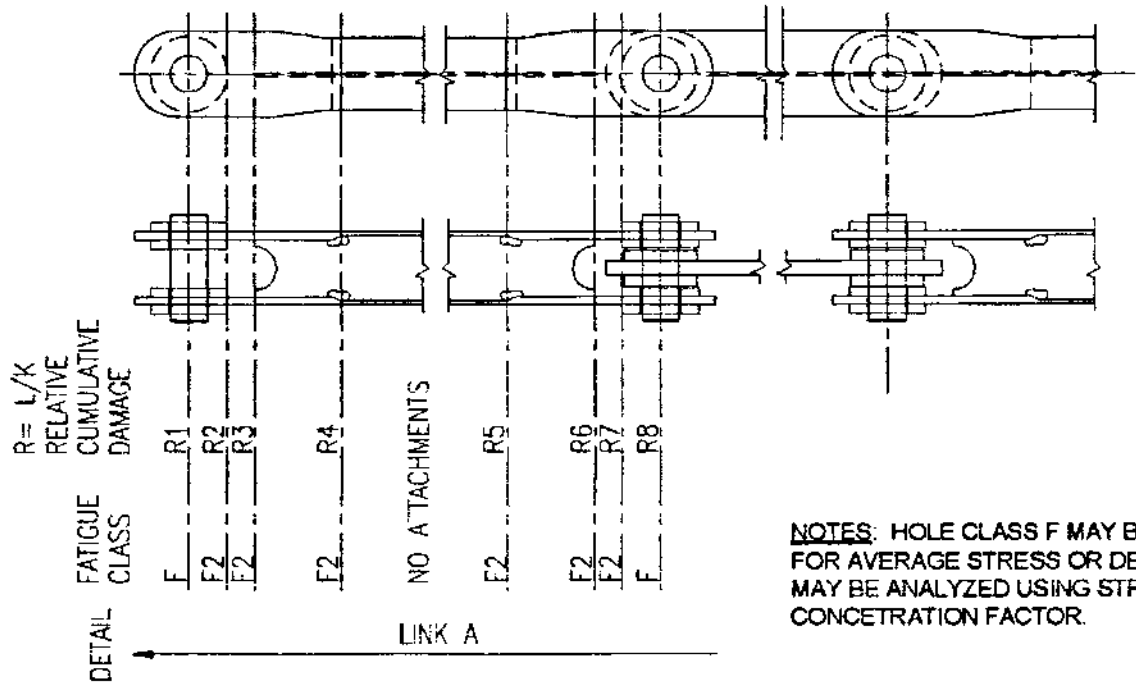
RELIABILITY OF SYSTEM SHALL BE CALCULATED BY DETERMINING THE RELIABILITY "D" OF EACH LINK INCLUDING ALL CONNECTION DETAILS, AND CALCULATING THE RELIABILITY OF THE SYSTEM USING:

$D_{SYSTEM} = D_A \times D_B \times D_C \ldots D_N$

FOR EXAMPLE, THE RELIABILITY OF LINK A IS
$D = D_1 \times D_2 \times D_3 \times D_4 \times D_5 \times D_6 \times D_7 \times D_8$
THE VALUES OF D_i ARE FOUND FROM TABLE FOR EACH R_i.

NOTICE WHEN $R \leq 0.4$, $D = 1$
AND WHEN THE CALCULATED STRESS RANGE IS ≤ 0.74 X ALLOWABLE STRESS RANGE, $R \leq 0.4$.

TYPICAL FORESTAY EXAMPLES



NOTES: HOLE CLASS F MAY BE USED FOR AVERAGE STRESS OR DETAIL MAY BE ANALYZED USING STRESS CONCETRATION FACTOR.

Liftech Standard Structural Details. Copyright ©1995, 2000, 2015 Liftech Consultants Inc.

2. General Arrangement Drawing

To be provided

3. Crane Weights and Declared Wheel Loads

To be provided

4. Existing Stow Pin and Tie-Down Details

To be provided

5. Existing Quay Details

To be provided

6. Crane End Stop Details

To be provided

7. Leewell Intelligent Monitoring System

Technical Solution of Intelligent Status Monitoring System

LW-TRD01-23083101

Project name: ICTSI [redacted]

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1 Overview

1.1 Inevitable process of equipment operation and maintenance in port industry

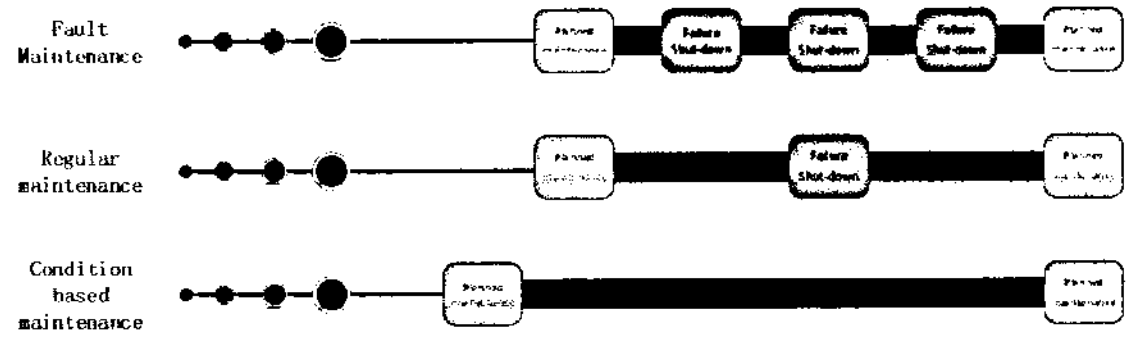
The port industry is asset intensive industry with high automation of equipment, strong continuity of production, and difficulty in inspection and maintenance. Once there is a malfunction, device will shutdown, or even major malignant accident of machine damage and casualty will occur. Therefore, it is objectively required that the operation and maintenance mode of equipment shall be changed to improve the operation and maintenance safety and production efficiency.

The necessity of intelligent operation and maintenance of equipment in port industry is mainly reflected in:

1. From passive rush maintenance to preventive maintenance strategy;

2. fixed item inspection mode is transformed into real-time monitoring;

3. Using real-time data interaction and analysis to realize intelligent operation and maintenance.



◎From passive rush maintenance to preventive maintenance strategy

At present, the equipment management strategies in the industry are mainly

breakdown maintenance and preventive maintenance. When enterprises make operation and maintenance decisions on equipment, they mainly rely on craft and experience, which is lack of effective equipment real time monitoring data as support. For example, the best maintenance time of bearings, gears, couplings and other components is determined on the basis of the past experience. Because the determination relies on static data, it is often impossible to find out the defects of the equipment and avoid the occurrence of equipment faults in time, especially the occurrence of unexpected faults. Therefore, the two strategies of breakdown maintenance and preventive maintenance can not meet the present operation and maintenance requirements of modern equipment.

○The fixed items inspections inspection method is transformed into real-time monitoring

At present, offline fixed items inspection inspection and monitoring methods are used on important equipment of the production line. This type of mode is still an equipment monitoring mode that centers around the fixed item inspection personnel of the equipment. It lacks effective control over the core of equipment status analysis and judgment--comparability, continuity ,timeliness and accuracy of "equipment operation data" , thereby it is difficult to get the operating status of the equipment in a timely, accurate and comprehensive manner, and many equipment on the site are not easy to reach, and the security for fixed item inspection is poor. Therefore, in order to ensure the safety, stability and long-term operation of the production line, and to carry out more scientific equipment operation, repair and maintenance, it is necessary to use online monitoring method to realize real-time control of the equipment status and achieve the aim of intelligent equipment operation and maintenance.

○Real-time data interaction and analysis are used to realize intelligent operation and maintenance

The current informatization management mode within the enterprises is a "traditional informatization" processing method. In essence, it is a computer system rearrangement of "historical archives data processed artificially" and "historical records data", which still relies on static data and focuses on the workflow.

Based on the different structure types and working conditions of the equipment, intelligent equipment operation and maintenance is relying on the sensor network device installed on the equipment to continuously obtain the vibration and temperature signals of the equipment in the operating status through wired or wireless or other means, and automatically collect real-time data from the equipment based on the system's established acquisition and alarm strategy and the mechanism of abnormal data automatically triggering the abnormal alarm to achieve real-time control of the health status of the equipment. For the processing of abnormal alarm equipment, professional data analysts or remote diagnosis experts use a special data analysis platform to analyze the vibration temperature signal in detail, and accurately determine the equipment failure location and cause based on the equipment structural characteristics, parameters, and historical operation and maintenance information, and determine the root cause of the failure, so as to achieve equipment predictive maintenance and rolling prediction of the lifespan of failed components and avoid the occurrence of corporate safety accidents.

1.2 Values of intelligent equipment operation and maintenance

The realization of intelligent equipment operation and maintenance can greatly improve the operating efficiency of enterprises, and help enterprises achieve the "bigger and stronger" goals. The specific values are as follows:

- Ensure that the company has no major accidents
- Effectively extend equipment life and improve equipment utilization
- Improve product output and quality
- Reduce equipment operation and maintenance costs

O Reduce waste of spare parts, reduce inventory and capital occupation

O Reduce the workload of enterprise personnel, improve work efficiency, and release human resources

O Reduce the dependence of enterprises for on site experts, integrate expert resources and provide professional services

1.3 Intelligent equipment operation and maintenance is able to realize malfunction diagnosis

Leewell intelligent equipment operation and maintenance solution is able to detect the following types of faults of rotating components:

No.	Malfunction types	Malfunction location	Malfunction description
1	Power frequency failures	Base failure	Motor, gear box base looseness, structure looseness, structure resonance
		Imbalance	Motor rotor imbalance, gear imbalance of gear box high speed shaft and roller
		Misalignment	Shaft system axis lines do not coincide
		Resonance failure	Resonance caused by the operating frequency of the motor and gear box consistent with the resonance frequency of the components
2	Motor faults	Stator winding	Short stator lamination or core looseness, stator eccentricity, loose stator winding, etc.
		Rotor winding	Looseness, fracture of rotor cage strip, rotor eccentricity, rotor thermal deformation, etc.
3	Mechanical parts damages	Motor	The inner and outer rings of the motor bearings are peeled off; the rolling elements are peeled off; the cage is scratched and broken; the bearings are subject to dynamic and static friction; the inner and outer rings are loosened in rotation with the great gap loose, shaft current, etc.
		Gear box	The inner and outer rings of the gearbox bearing are peeling off; the rolling elements are peeling off; the cage is scratched and broken
			Gear teeth broken, gear misalignment,gear pitting and wear, etc.
		Shaft system	Inner and outer ring of shaft system support bearing peeling off; rolling elements peeling off; scratching and breaking of

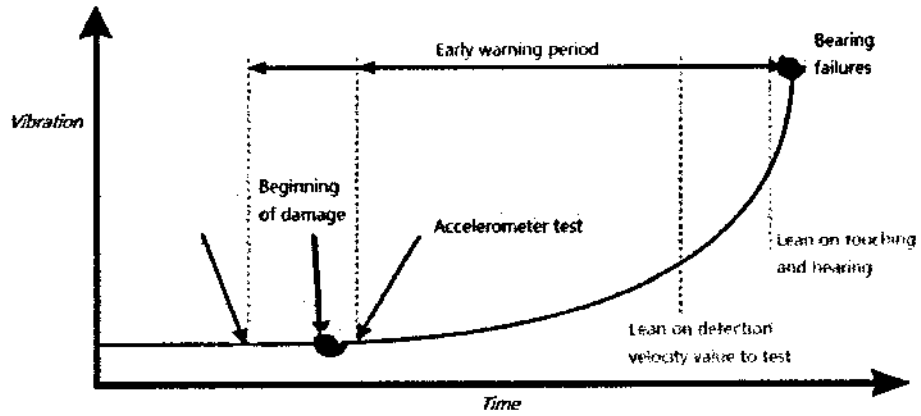
			cage; bearing dynamic and static friction; weared bearing inner or outer ring; Rotation looseness and cooperation looseness, etc.
			Shaft bending, coupling wear, rotation shaft displacement, etc.

1.4 Comparison of common monitoring methods

	Imbalance	Misalignment	Lack of lubrication	Malfunction of engagement	Malfunction of blade	Resonance of components	Belt Vibration	Malfunction of bearing
Temperature Analysis	X	X	X	X	X	X	X	√
Sound Analysis	X	X	X	X	X	√	X	√
Oil Analysis	X	X	√	√	X	√	X	√
Vibration Analysis	√	√	√	√	√	√	√	√

1.5 Typical cracking process of bearing and monitoring solution

Adopting condition base maintenance mode can monitor and warn effectively in the early stage of equipment occur damage, the adoption of maintain solution through warning, which can extent the service life of equipment.



2 Introduction to Core Hardware

2.1 Vibration accelerometer

Vibration acceleration sensors LMH1229T, LMH1237T and LML1230T are the most widely used sensors in the field of vibration monitoring currently. They have the advantage of a wider frequency range. Meanwhile, it is easy to be mounted by means of screws, adhesives, etc. The sensor fully meets the requirements of a variety of harsh environments on site with stable signal acquisition, high frequency response, wide range characteristics, built-in IEPE circuit, isolated output, constant current source power supply and so on.

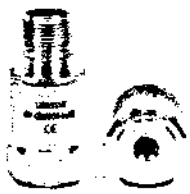
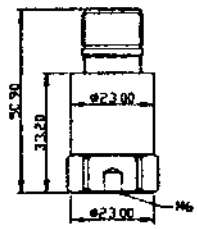
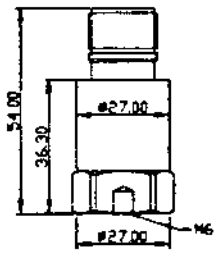
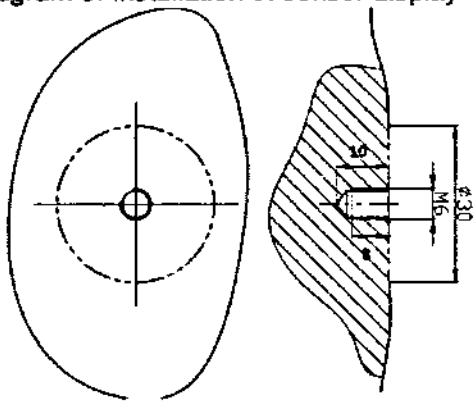
Sensor name	Sensor image	Front view of sensor	Top view of sensor
LMH1229T			
LML1230T			

Diagram of Installation of sensor display



(1) Connect with military plug MIL-C-5015 and can be used for online monitoring of harsh industrial sites.

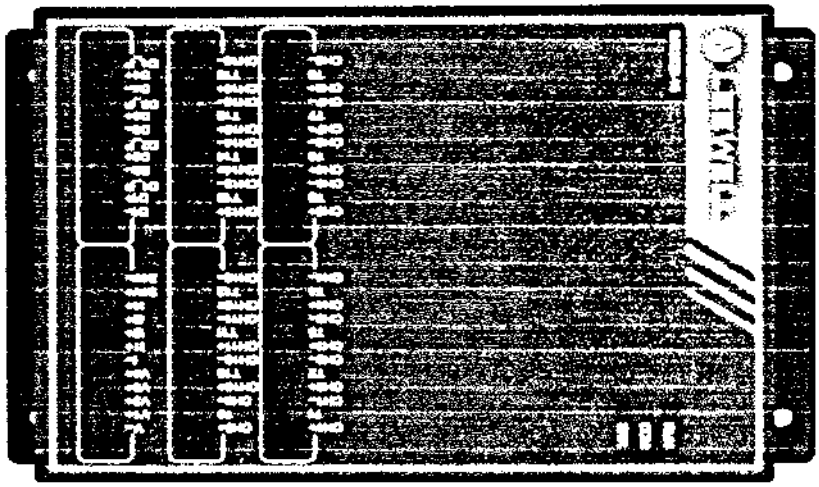
(2) Wider broadband sound range 0.5~12KHz

(3) Wider acceleration measurement range ±80g

(4) Temperature measurement range -40~120℃

2.2 Online monitoring station LMS2020

LMS2020 online monitoring station combines the latest hardware technology with network communication technology and with LEEWELL's many years of experience in the field of equipment monitoring. It is an intelligent unit launched on the basis of customer requirements with integrating collected vibration data, temperature data, speed data, oil level, oil temperature data and other analog data to store and forward these data. It communicates with the upper layer through methods such as RJ45, optical fiber, RS485, etc. and supports 16-channel vibration and temperature signal acquisition module, 4-channel process acquisition module and 2 rotation speed channels.



In addition to the functions such as online collection of the real time vibration data, data storage and transmission under alarm and periodic conditions, online monitoring station also has the following special functions:

1) Long waveform acquisition: easily collect spectrum and waveform data whose resolution ratio is greater than 0.012HZ, sampling time more than 81.29s and it satisfies diagnosis requirements of low speed spare parts.

2) Full sampling technology: monitoring system continuously collects vibration data in 24 hours. Data collection is comprehensive, including regular vibration data, long waveform, time domain index (kurtosis, peak, valid value), etc.

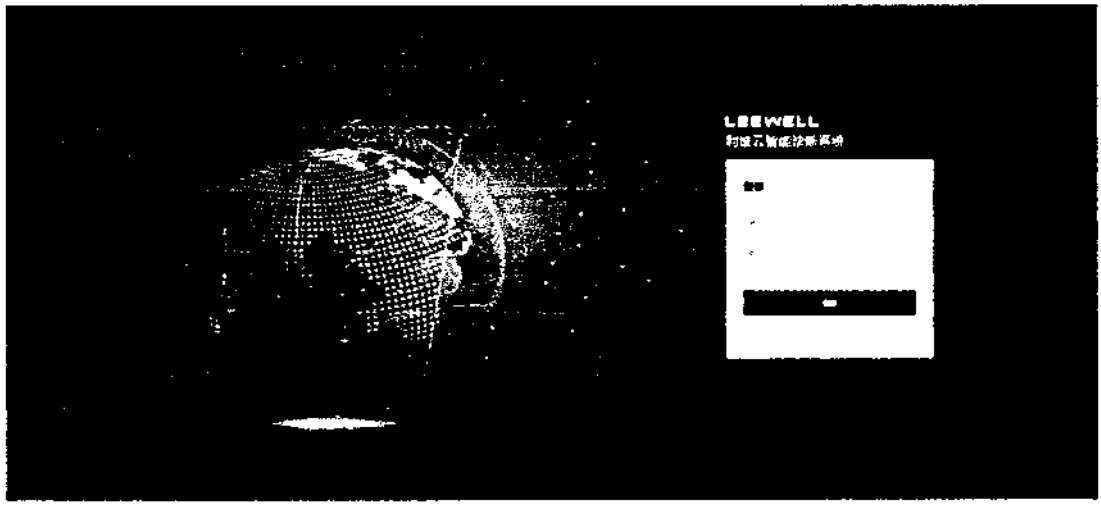
3) Fully synchronous acquisition: signals of all Channels in monitoring system are collected at same time. Vibration and temperature signals of monitoring points can be analyzed in one spectrum.

4) Favorable extendability: it can access to vibration, rotation speed, oil level , audio and temperature signals.

2.3 System software ISMS2000

Status monitoring system is an important human-computer interaction platform to read, view, scan and analyze data. It judges the operation state of motor, gearbox and

drum bearing through specific analysis on vibration data, whereby performing comprehensive data analysis and predicting QC/QC hidden trouble in advance, judging the degree of malfunction, precisely locating malfunction position and avoiding unplanned shutdown. Meanwhile it provides decision-making basis for rational maintenance. The distributed architecture design it adopts has good openness and extensibility with data filtering and data management function to perform deep data mining.



A) The system adopts B / S architecture design and distributed architecture for site and remote center respectively to deploy the system architecture.

B) The system integrates more than 30,000 types of bearing models and parameters of the database. It has a full range of transmission structure type. Enter the corresponding bearings and gear teeth and other information, the automatic calculation of defects features frequency in each bearing gear transmission of driving mechanism will be deployed. Therefore the defect features frequency of gears will be identified quickly.

C) The system has template creation and updating capabilities. It comes with

template equipment, customizes the template device, quickly configures device information, completes single or multiple unit acquisition strategy updates, at the same time can be used to import and export system functions and update the template the alarm value.

D) The system has remote monitoring capabilities and powerful data filtering capabilities. The data needs to be analyzed can be easily filtered when analyzing data through setting filter conditions such as sample values, frequency, time range, high-pass filtering, etc.

E) The system supports standard absolute alarm values such as ISO 10816 to be set, which perform statistical analysis on historical data, updated fault alarm value by historical data statistics to realize the dynamic adjustment of alarm values according to the state of equipment.

F) The system integrates configuration and data analysis in one and supports OPC server software functions.

G) The system has the function of viewing trends. It classifies and collects data such as vibration and impact on the basis of rotation speed, power and load, and establishes corresponding trend charts to facilitate operators to observe and analyze the trend of unit vibration status and timely take appropriate treatment measures including:

① In the trend analysis chart, check the trend of vibration sampling values that change with time and defined by each measurement under motor monitoring points.

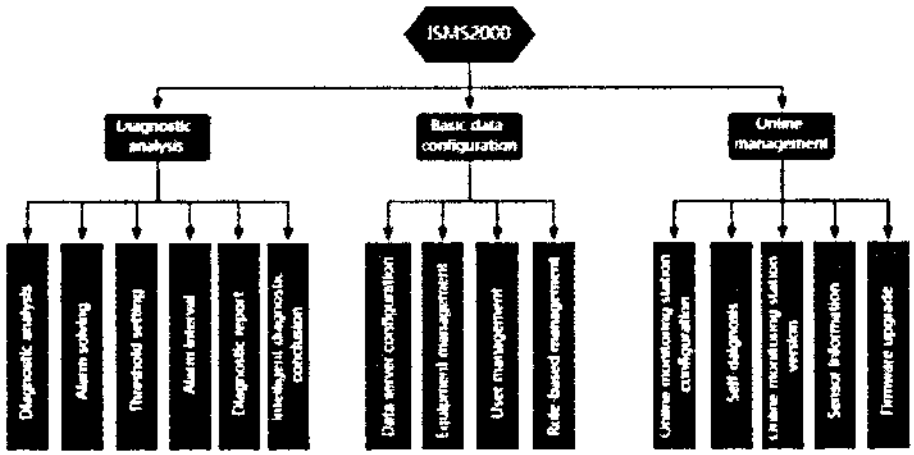
② In the Trend Analysis Diagram, select "Show Alarm Line", the alarm threshold line will be displayed according to the representative color of the alarm level.

(8) The system uses time-domain waveform, spectrum, envelope demodulation and other related tools to diagnose and analyze. Combined with optional fault symptoms, the system diagnoses the working conditions of units to obtain specific fault, location, causes and other information of the unit.

(9) The system provides loads of data analysis functions:

- Time domain waveform, spectrum analysis, multi-time domain waveform analysis, multi-spectrum analysis, long time domain waveform analysis, rotation speed data analysis.
- Trend analysis, multi-trend analysis, sampling value trend analysis, frequency trend analysis, long waveform trend analysis, waterfall plot.
- Envelope demodulation, cepstral analysis, order analysis.
- Cross phase spectrum, waveform reprocessing.

2.4 Software functional architecture



The software system consists of three functional modules: diagnostic analysis, basic data configuration and online management. Diagnostic analysis module provides diagnostic analysis, alarm setting, threshold setting and other functions, which can provide favorable data support for users' equipment management. Basic data configuration includes user management, equipment management, role-based management and server configuration,. The server configuration can adopt distributive mode to meet the continuous capacity expansion during port construction and solve the problem of incompatibility caused by the deployment of a single server architecture.

2.5 Software Diagnostic Analysis

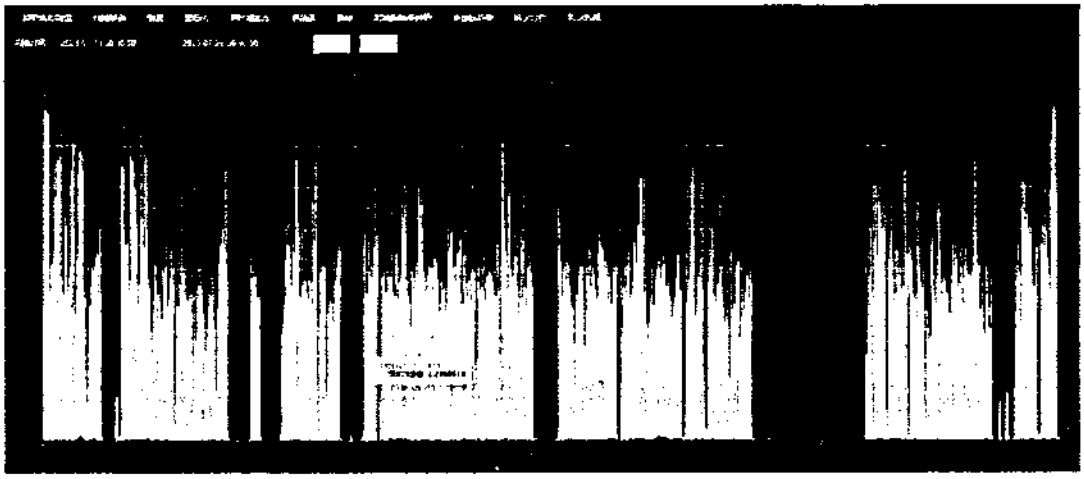
2.5.1 Overview page of software

The overview page of software diagnosis provides nice interface of mechanism monitoring points, which can reflect the health status intuitively, monitoring points present different colors to reflect the grade of alarm if triggering threshold alarm.



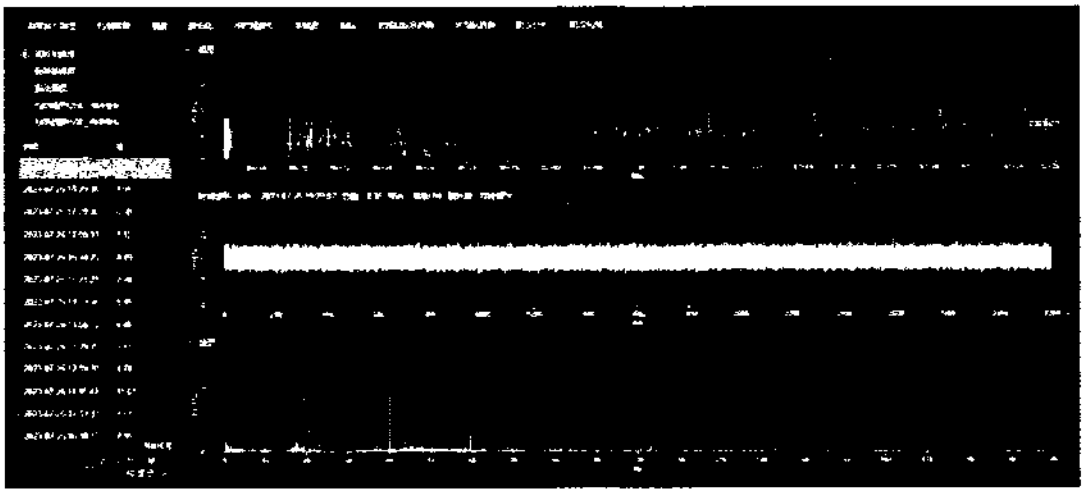
2.5.2 Trend page for multiple indicators

The multi-indicator trend function allows clients to compare and analyze the health status of devices in different dimensions. After the data is transformed and analyzed, can select and display indicators such as the device speed, temperature, high-frequency total value, total low-frequency value, total speed value, gear envelope, and bearing envelope.



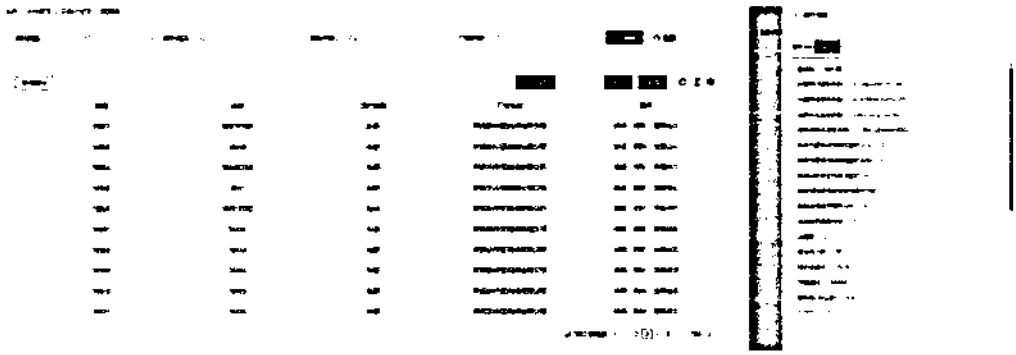
2.5.3 Time domain waveform multiple indicators

The multi-trend analysis of time-domain indicators shows the variation trend of the total value, peak value, peak-peak value, beauty index, pulse index, waveform index, margin index, skew index, peak value index, root index, maximum value, minimum value, mean value and average amplitude of multiple wave forms at a certain measurement point.



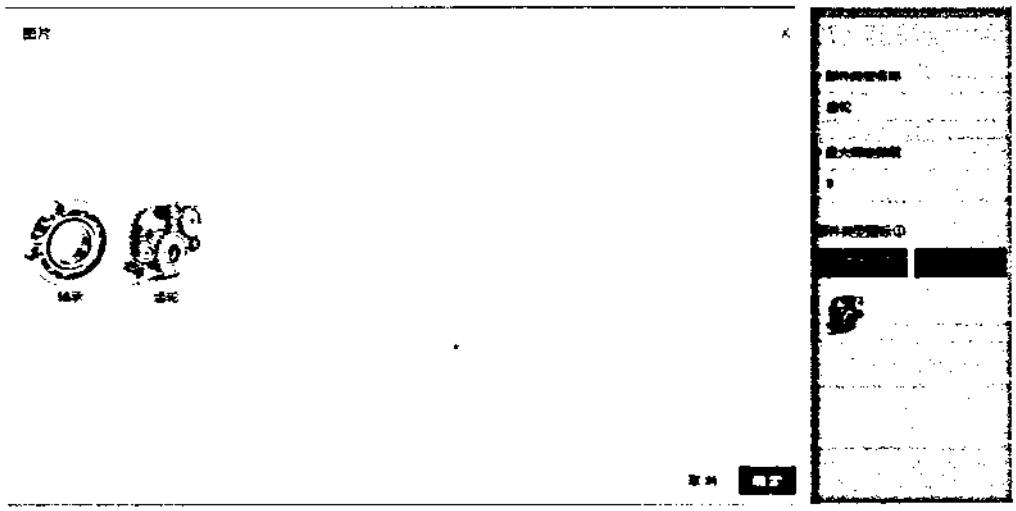
2.5.4 Bearing Database

There are around 40-thousand kinds of bearing database, which covering about 99% of the bearing types of port machinery equipment condition monitoring institutions.



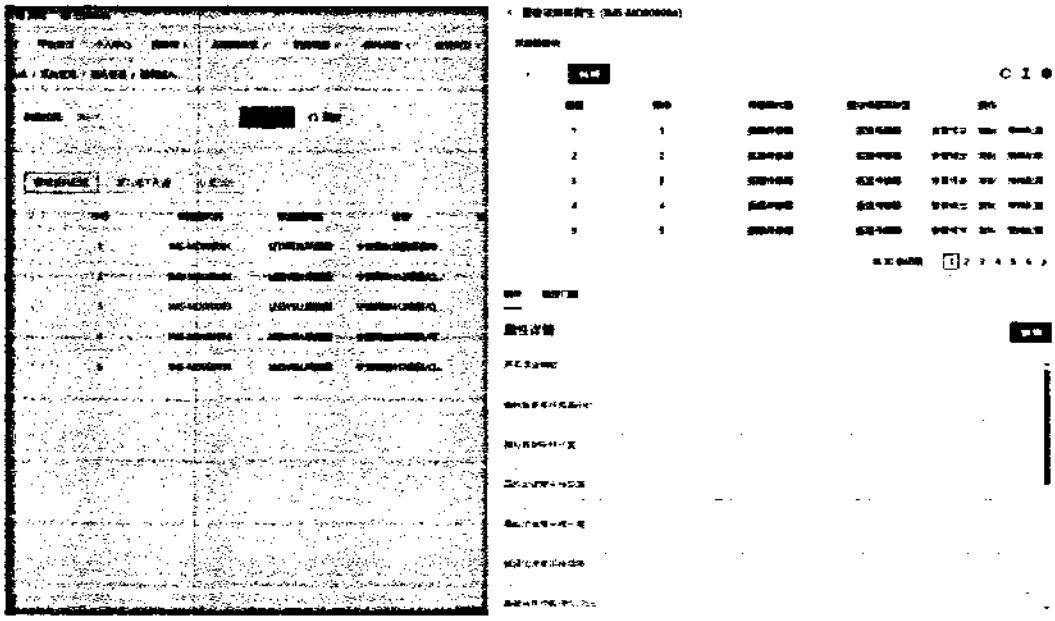
2.5.5 Graphic parts Library

During the editing and debugging of the device and organization, can add associated and fixed device components according to the actual device model. Users can add graphics components according to the actual situation of the project.



2.5.6 Strategy of Data Collection

Compared with the traditional timing collection strategy, LEEWELL introduced the triggering collection strategy, which can select acquisition strategies such as speed, vibration speed, acceleration, speed + vibration speed and speed + acceleration according to the working conditions of the field equipment. Meanwhile, it also added functions such as triggering the impact threshold to capture abnormal impact signals.



3 Design

3.1 Solution design principle

LEEWELL status monitoring sensor and system will design the solution according to the structure and application characteristics of port machinery, referring to the relevant standards of crane and vibration monitoring, and combining with the actual field application.

The criteria are as follows:

1、GB/T 3811: Crane design criterion.

2、GB/T20863.5-2007: Crane classification - part 5: Quay Crane & Portal Crane

3、ISO10816-3 & GBT 6075.3-2011: Mechanical vibration measurement and evaluation of machine vibration on non-rotating parts-part 3: measured on site industrial machines whose rated power is greater than 15kW and rated speed between 120r /min and 15000r/min.

4、ISO/CD 13373-1: Condition monitoring and mechanical diagnosis - vibration condition monitoring - part 1 general principles.

3.2 Software and PLC synchronous alarm solution

The monitoring station has two-way data output. In one way the waveform data is transmitted to database of server terminal through Ethernet TCP/IP protocol, In the other way, the station transmits data to PLC by Modbus RTU communication interface and communication conversion module through PROFIBUS DP / PROFINET.

The station end has 13 algorithm indexes. If the data triggers alarm after the operation and judgment inside the station, alarming state (1/0) of the Channel will be transmitted to PLC system through communication interface Modbus RTU. The algorithm indexes include total value, kurtosis, ultra-low frequency, low frequency, medium frequency, high frequency and r.m.s. velocity. Among the above indicators, the automatic alarm information of the overall value of vibration speed is used to reflect the overall state of the running equipment in real time, and the overall value of vibration is the basic standard in ISO10816 international criteria. Meanwhile the monitoring station will upload data to online analysis software through Ethernet and the analysis software also performs index and data comparison to judge whether alarm is triggered. If the alarm does triggered, the alarm data type and waveform data will be viewed in software

end and detail data analysis can be deployed.

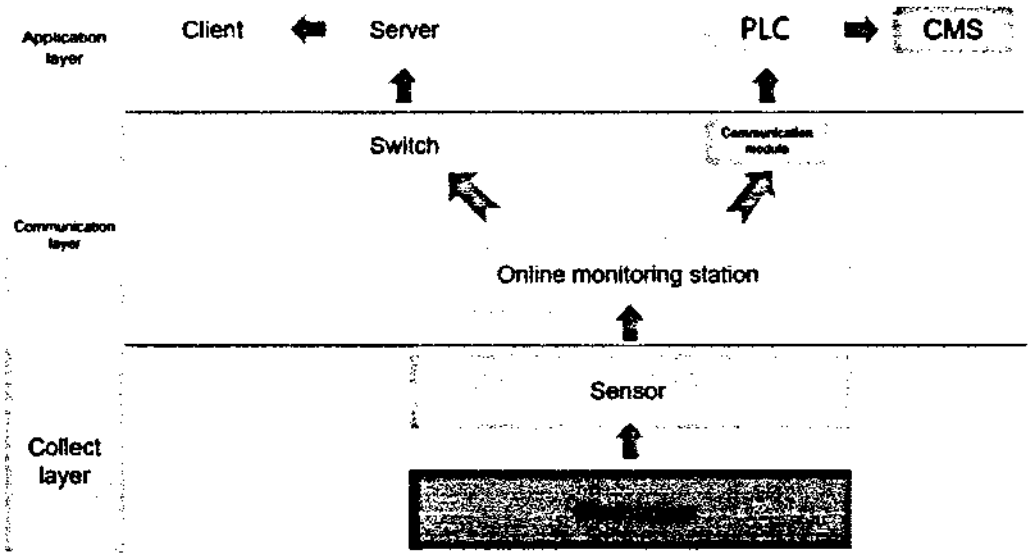
PLC Communication data sheet					
Address	Byte	Bit	Note	Data type	Unit
0	2	16 bit	Rotation speed 1	UNSIGNED SHORT	rpm
2	2	16 bit	Rotation speed 2	UNSIGNED SHORT	rpm
4	4	32 bit	Process information 1	FLOAT	
8	4	32 bit	Process information 2	FLOAT	
12.0	2	1 bit	Channel 1 vibration alarm	BOOL	0,1
12.1		1 bit	Channel 2 vibration alarm	BOOL	0,1
12.2		1 bit	Channel 3 vibration alarm	BOOL	0,1
12.3		1 bit	Channel 4 vibration alarm	BOOL	0,1
12.4		1 bit	Channel 5 vibration alarm	BOOL	0,1
12.5		1 bit	Channel 6 vibration alarm	BOOL	0,1
12.6		1 bit	Channel 7 vibration alarm	BOOL	0,1
12.7		1 bit	Channel 8 vibration alarm	BOOL	0,1
13.0		1 bit	Channel 9 vibration alarm	BOOL	0,1
13.1		1 bit	Channel 10 vibration alarm	BOOL	0,1
13.2		1 bit	Channel 11 vibration alarm	BOOL	0,1
13.3		1 bit	Channel 12 vibration alarm	BOOL	0,1
13.4		1 bit	Channel 13 vibration alarm	BOOL	0,1
13.5		1 bit	Channel 14 vibration alarm	BOOL	0,1
13.6		1 bit	Channel 15 vibration alarm	BOOL	0,1
13.7		1 bit	Channel 16 vibration alarm	BOOL	0,1
14	4	32 bit	Channel 1 r.m.s. velocity	FLOAT	mm/s
18	2	16 bit	Channel 1 temperature	SHORT	℃
20	4	32 bit	Channel 2 r.m.s. velocity	FLOAT	mm/s
24	2	16 bit	Channel 2 temperature	SHORT	℃
.....					
98	4	32 bit	Channel 15 r.m.s. velocity	FLOAT	mm/s
102	2	16 bit	Channel 15 temperature	SHORT	℃
104	4	32 bit	Channel 16 r.m.s. velocity	FLOAT	mm/s
108	2	16 bit	Channel 16 temperature	SHORT	℃

3.3 CMS interface (Made by crane manufacturer)

3.3.1 Vibration detection indicators are displayed on the CMS

LEEWELL intelligent status monitoring system, installs accelerometer and other sensors on the motor, gear box and other positions of port machinery, such as hoist, trolley and other important mechanisms. To achieve the status monitoring of port equipment through data collection by online monitoring station, which has supported the predictive maintenance of equipment.

The data collected by the online monitoring station can be transmitted back in two ways, One is sending collected status data to the remote control center, the other way is using PROFINET or PROFIBUS to report the index values and alarm to PLC in real time through the communication protocol conversion module.



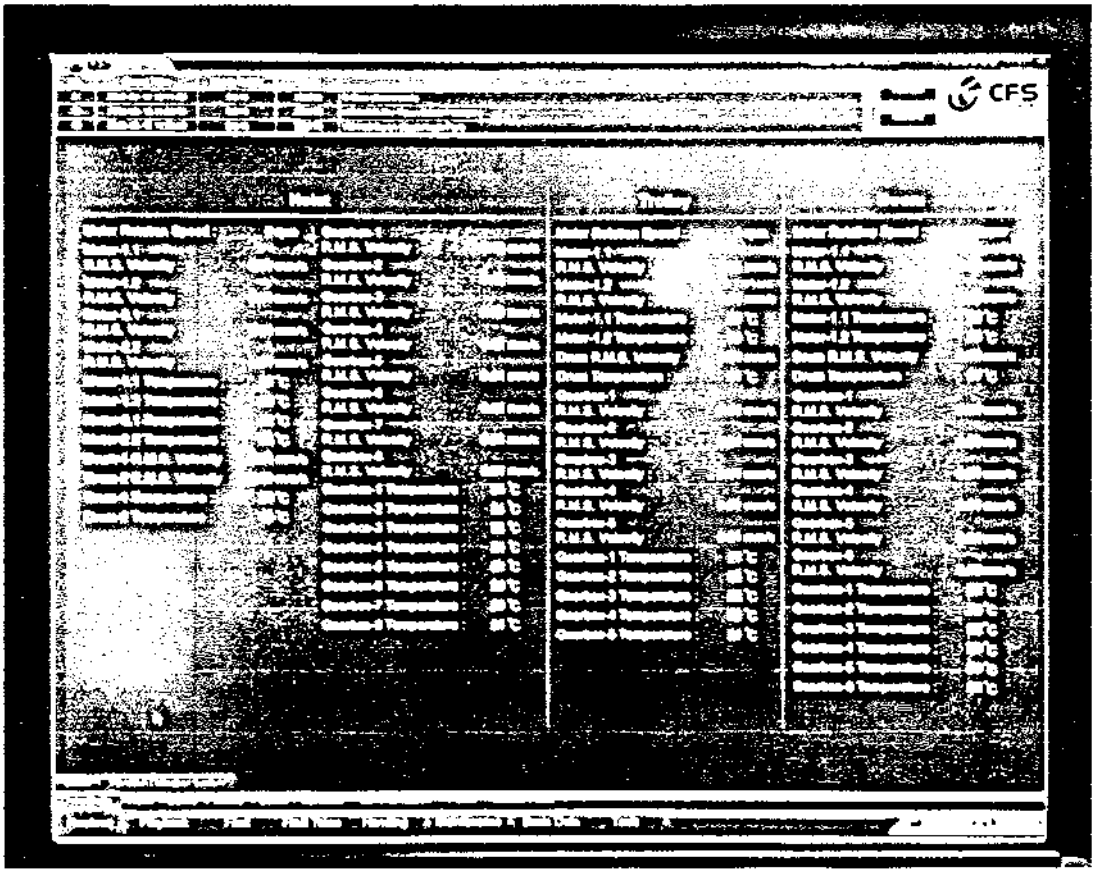
3.3.2 Display mode requirements and schematic

The requirements are as follows:

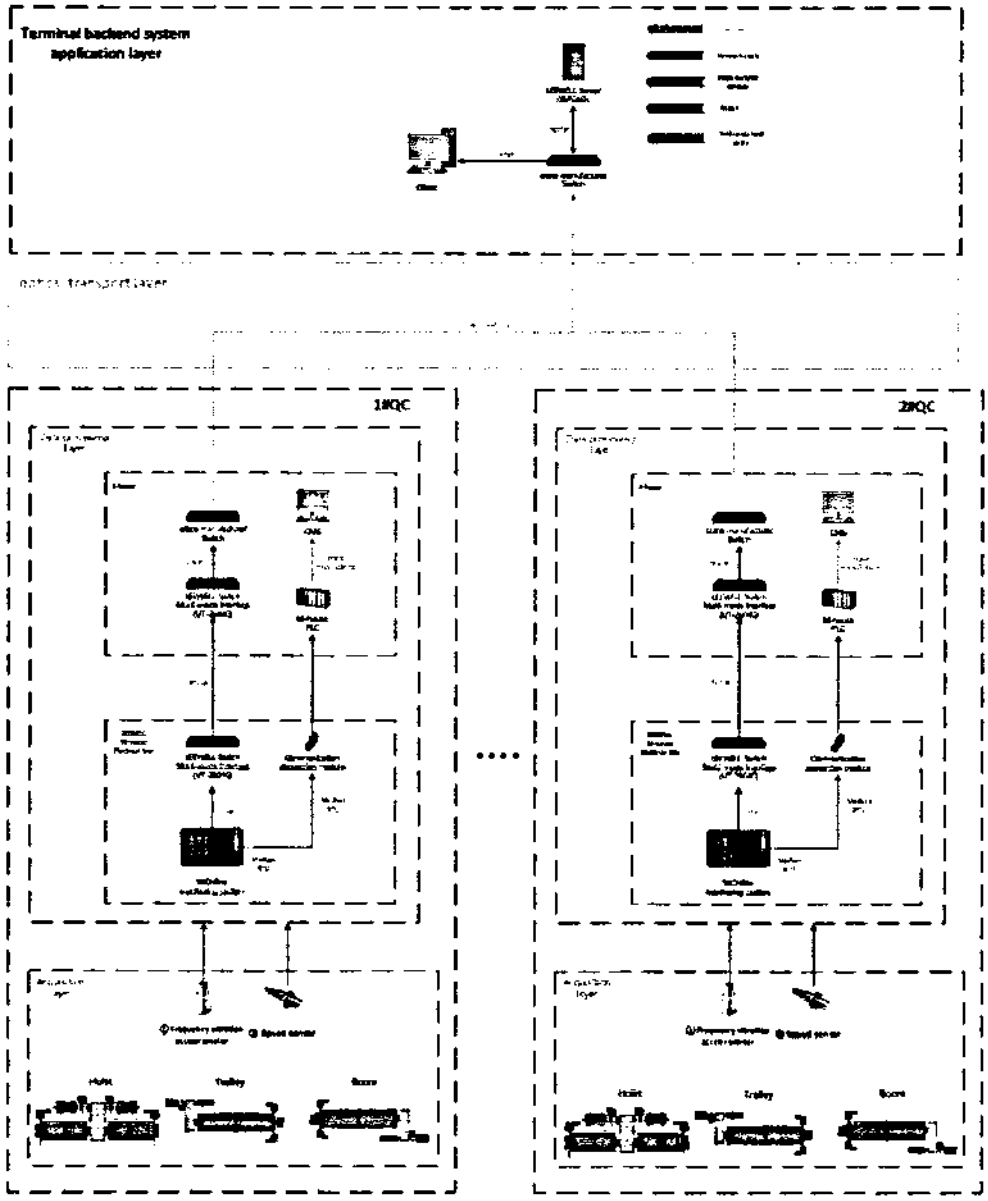
1. Add a sub-page of "vibration monitoring" for switching and viewing in "Real-time status" under the module of "Equipment status" on CMS.

2. The display of CMS according to the classification of port equipment, corresponding to the name of the measuring point, the name of the display index and the real-time index value.

The local CMS page is displayed below,



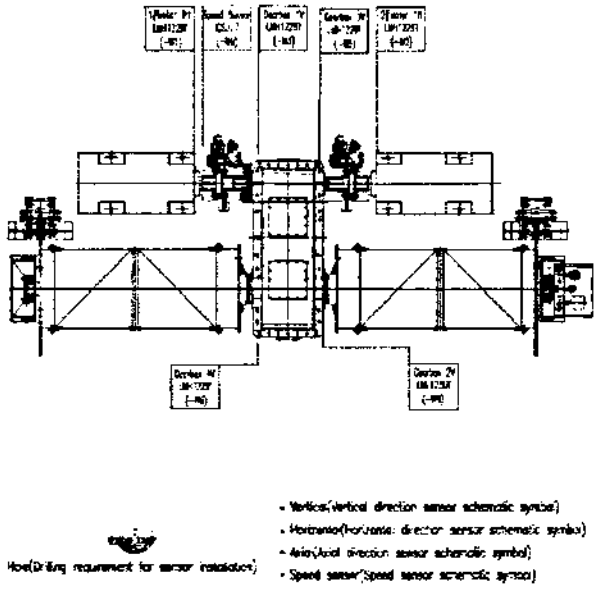
3.4 System topology



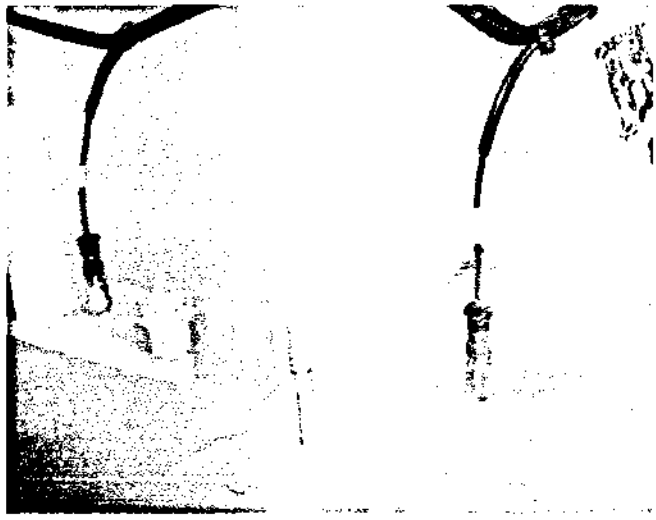
3.5 Configurations of different mechanisms

3.5.1 Distribution map and configuration table of monitoring points on hoist

Distribution map of monitoring points on hoist mechanism



Real application representative diagram of hoist drive mechanism monitoring points

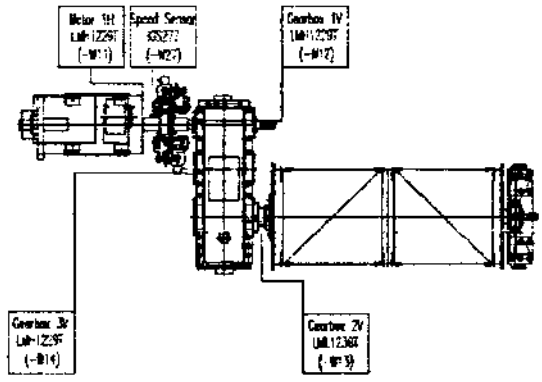


Configuration table of hoist drive mechanism (Unit)

Mechanism	Monitoring position	Monitoring content	Number of monitoring points (piece)
Hoist drive mechanism	Motor	Vibration+Temperature	2
		Rotation speed	1
	Gear box	Vibration+Temperature	4

3.5.2 Distribution map and configuration table of monitoring points on trolley

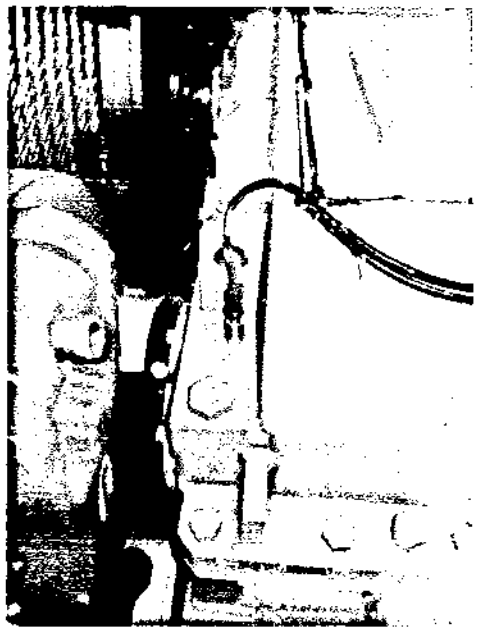
Distribution map of monitoring points on trolley mechanism



Hole(Drilling requirement for sensor installation)

- Vertical(Vertical direction sensor schematic symbol)
- Horizontal(Horizontal direction sensor schematic symbol)
- Axial(Axial direction sensor schematic symbol)
- Speed sensor(Speed sensor schematic symbol)

Real application representative diagram of trolley drive mechanism monitoring points

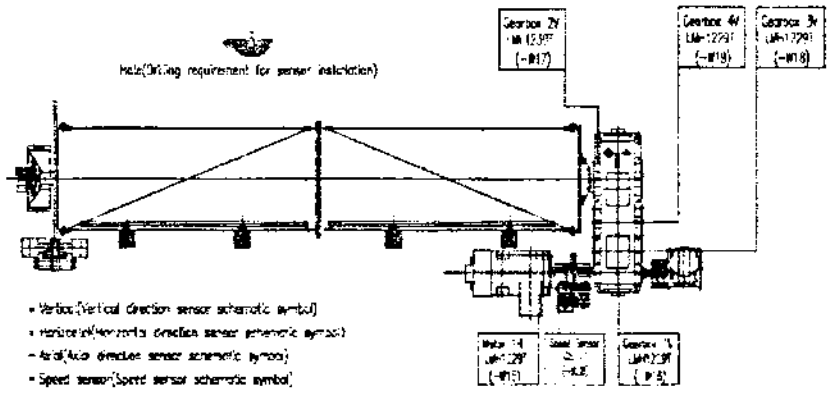


Configuration table of trolley drive mechanism (Unit)

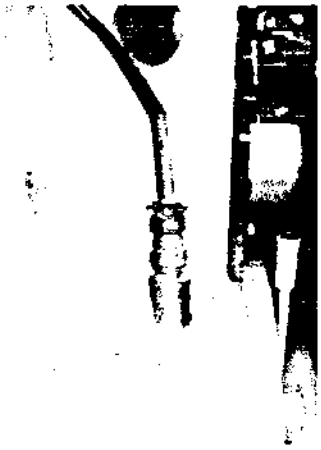
Mechanism	Monitoring position	Monitoring content	Number of monitoring points (piece)
Trolley drive mechanism	Motor	Vibration+Temperature	1
		Rotation speed	1
	Gear box	Vibration+Temperature	3

3.5.3 Distribution map and configuration table of monitoring points on boom

Distribution map of monitoring points on boom mechanism



Real application representative diagram of boom drive mechanism monitoring points



Configuration table of boom drive mechanism (Unit)

Mechanism	Monitoring position	Monitoring content	Number of monitoring points (piece)
Boom drive mechanism	Motor	Vibration+Temperature	1
		Rotation speed	1
	Gear box	Vibration+Temperature	4

3.5.4 Distribution table of online monitoring station

We obtain the distribution table given below from monitoring points of different mechanisms given above.

Mechanism	Hoist drive mechanism	Trolley drive mechanism	Boom drive mechanism
Number of monitoring points (piece)	6	4	5
Number of speed sensor (piece)	1	1	1
Monitoring station	16-channel online monitoring station		
Installation position	M-house		

3.6 System configuration

Main Configuration (equipment) List for QC (Unit)

No.	Monitoring Position		Description of Material	Specifications and Models	unit	Qty
1	Online Monitoring Station (16 channel)			IMS2023-16-4G-0	Piece	1
2	Hoist	Motor	High-frequency vibration accelerometer	LMH1229T	Piece	2
			Speed sensor	IGS277	Piece	1
		Gear box	High-frequency vibration accelerometer	LMH1229T	Piece	3
			Low-frequency vibration accelerometer	LML1230T	Piece	1
		Motor	High-frequency vibration accelerometer	LMH1229T	Piece	1

3	Trolley		Speed sensor	IGS277	Piece	1
		Gear box	High-frequency vibration accelerometer	LMH1229T	Piece	2
			Low-frequency vibration accelerometer	LML1230T	Piece	1
5	Boom	Motor	High-frequency vibration accelerometer	LMH1229T	Piece	1
			Speed sensor	IGS277	Piece	1
		Gear box	High-frequency vibration accelerometer	LMH1229T	Piece	3
			Low-frequency vibration accelerometer	LML1230T	Piece	1
6	Switchboard (E-house)			UT-2604G	piece	1
7	Integrated custom-made electrical cabinet		SS316 cabinet box + configuration equipment	Including cabinet box (SS316 material, 800*600*250mm),power supply, air switch, surge protective device, thermostat switch	piece	1
			Communication converter	PROFINET/PROFIBUS	piece	1
			Switchboard	UT-2604G	piece	1
8	Cable, connector and auxiliary installation materials		Sensor cable and connector	M12 straight metal 3-core A-hole PG7 plug, Teflon shielded wire, minimum bending radius 25mm	lot	1
			Auxiliary installation materials	fixed rolling belt,winding pipe, terminal and other installation accessories	lot	1
9	Technical Service (Install in crane manufacturer's base and debug in port)				Lot	1

Terminal back-end system configuration

No.	Description of Material	Specifications and Models	Unit	Qty
1	Display	DELL	Piece	1
2	Server	DELL R450 (with bracket and operating system)	Piece	1
3	Local diagnosis and analysis software	ISMS2000 software system +	Piece	1

ITEM 18 : ELECTRICAL WORKS

GENERAL DESCRIPTION

The work to be done under this Item of Specifications consists of fabrication, furnishing, delivery and installation, complete with all details of electrical work, in the subject area and all work materials related to the proper completion of the installation, except for those parts of the work that are expressly stated to be performed by others. All works shall be in accordance with the governing Codes and Regulations and the Specifications, unless the same are inconsistent with such codes, etc., as may later govern. The requirements regarding the materials and equipment required for the complete installation of the work specified herein and indicated on the drawings. The Specifications are intended to provide a broad outline of the equipment required, but are not intended to include all design details and construction specifications.

WORK INCLUDED

The work to be done under this Item shall include the furnishing of all tools, labor, supervision, equipment, fixtures and all necessary materials, each complete and in proper working condition unless one or other is specifically excluded or stated otherwise in this specifications but not limited to the following items of works.

a. All works and material for a complete lighting and power systems including cables and conduits, circuit breakers, panel board and connection to all lighting fixtures and power outlets, air condition, switches, supports and accessories.

b. All steel support for conduits, wires, panel board, boxes, lighting fixtures, etc. as indicated or as required to the completion of the installation.

c. Termination of all electrical system and the complete grounding system.

d. A complete testing and commissioning of all electrical and auxiliary systems. The Contractor shall provide all necessary testing instruments.

e. All items incidentals to and or required for the proper completion such as painting of boxes, conduits and the likes.

f. Test, supply and install Pad Mounted Transformer including all wiring accessories and terminations as indicated on the drawing.

g. Test, supply and install High / Low Voltage Switchgear, Synchronizing Panel including all necessary intelligence unit and all interconnecting cables, cable support and connectors.

h. Test, supply and install brand new Stand-by Generator Set including all necessary accessories.

i. Furnish and install all civil work items related to the electrical installation including first private pole / primary pedestal pole, concrete encasement of conduits, manholes, hand holes, equipment pads, cable tray, trench, metering equipment pedestal, etc.

j. Termination of all feeders at High / Low Voltage Switchgears inclusive of wires and cables and the necessary cable connectors.

k. Furnish and install primary lines, power and auxiliary system feeders, branch circuits and equipment inclusive of all conduits, fittings, wirings and accessories and the termination of the same.

l. Furnish and install all exterior and interior lighting and power wirings including conduits, boxes, gutters, fittings, wiring accessories, and terminations.

m. Coordination with other companies/offices including handling of all material related to material testing and application of electrical permits in the expense of the Contractor.

n. Preparation of necessary shop drawings required for the proper execution of the works subject to the approval of the Engineer.

QUALITY ASSURANCE

A. Qualification of Manufacturer's:

Furnish manufacturer's electrical equipment of the types and sizes specified which has successfully operated for not less than the past two years. Manufacturer for Transformer and Generator Set shall be a public listed power generation manufacturing company and shall have a Certificate of ISO 9001 certified company.

B. Factory Tests are required for all electrical equipment and assemblies. Perform factory tests in accordance with the codes and standards specified as applicable to the equipment. Items to be factory tested before ship/deliver to site shall include:

1. Transformer
2. High / Low Voltage Switchgear
3. Automatic Synchronizing Panel
4. Generator Set

C. Factory Inspection:

PPA's representative/s may inspect fabricated electrical equipment at the factory. Notify PPA's representative/s in sufficient time so that factory inspection can be arranged. Factory inspection will be made after manufacturer has performed satisfactory checks, adjustments, tests and operations. Approval of equipment at the factory only allows the manufacturer to ship/deliver the equipment to the site, and does not constitute final acceptance. All expenses required for this work shall be obtained by and at the expense of the contractor.

SUBMITTALS

Obtain approval before procurement, fabrication or delivery of items to the job site. Partial submittals will not be entertained and will be returned without review. Submittals shall include the manufacturer's name, trade name, place of manufacturer, catalogue model of number, nameplate data, size, layout dimensions, capacity, project specification and paragraph reference and technical society publication references, and other information necessary to establish contract compliance of each item to be furnished.

a. Shop Drawings

In addition to the requirements of the contract clauses, shop drawings shall meet the following requirements:

1. Drawings shall be a minimum of 210 mm x 297 mm in size or in A3 size, except as specified otherwise.

2. Drawings shall include wiring diagrams and installation details indicating the proposed location layout and arrangement, control panels, accessories, and other items that must be shown to assure a coordinated installation.

3. Wiring diagrams shall identify circuit termination and the internal wiring for each item of equipment and its interconnection.

4. Drawings shall indicate adequate clearances for operation, maintenance and replacement of equipment devices. If the layout is disapproved, revise the layout and resubmit.

b. Manufacturer's Data

Submittals for each manufactured item shall include manufacturer's descriptive literature, equipment drawings, diagrams, performance and characteristic curves and catalog cuts. Each submittal shall have the manufacturer's name, trade name, catalogue model or number, name plate data, size, layout dimensions, capacity, specification references and all other information necessary to establish contract compliance.

c. Standard Compliance

When material or equipment must conform to the standards of organizations such as American National Standard Institute (ANSI), American Society for Testing and Materials (ASTM), National Electrical Manufacturer's Association (NEMA) and Underwriters Laboratories (UL), proof of such conformance shall be submitted to the Engineer for approval.

If an organization uses a label or listing to indicate compliance with a particular standard, the label or listing will be acceptable evidence, unless otherwise specified in the individual sections. In lieu of the label or listing, the Contractor shall submit a certificate from an independent testing organization, which is competent to perform acceptable test and is approved by the Engineer. The certificate shall state that the item has been tested in accordance with specified organization's test methods and that the item conforms to the specified organization's standard. For materials and equipment whose compliance with organizational standards or specifications is not regulated by an organization using its own listing or label as proof of compliance, a certificate of compliance from the manufacturer shall be submitted for approval.

The certificate shall identify the manufacturer, the product and the referenced standard and shall simply state that the manufacturer certifies that the product conforms to all requirements of the project specification and of the referenced standards listed.

DELIVERY AND STORAGE

Equipment and materials shall be properly stored and adequately protected and carefully handled to prevent damage before and during installation. Equipment and materials shall be handled, stored and protected in accordance with the manufacturer's recommendations and as approved by the Engineer. Electrical conduit shall be stored to provide protection from the weather and accidental damage. Cables shall be sealed, stored and handled carefully to avoid damage to the outer covering or insulation and damage from moisture and weather. Damaged or defective items shall be replaced with new items at no cost to the Owner.

CATALOGUED PRODUCTS

Materials and equipment shall be catalogued products of manufacturers regularly engaged in production of such materials or equipment and shall be at manufacturer's latest standard design that complies with the specification requirements. When two or more units of the same type, class and size of equipment are required, these units shall be products of a single manufacturer; however, the component parts of the system need not be the products of the same manufacturer. Each major component of equipment shall have the manufacturer's name, address and the model of the serial number on a nameplate securely affixed in a conspicuous places, the name plate of the distributing agent will not be acceptable.

MANUFACTURER'S RECOMMENDATIONS

Where installation procedures or any parts thereof are required to be in accordance with manufacturer's recommendations, furnish printed copies of the recommendation prior to installation. Installation of the items shall not proceed until recommendations are received. Failure to furnish recommendations shall be cause for rejection of the equipment or materials.

WORKMANSHIP

The work throughout shall be executed in the best and most thorough manner under the direction of the Contractor and to the satisfaction of the Owner and Engineers, who will jointly interpret the meaning of the drawings and specifications and shall have the authority to reject any work materials which, in their judgment, are not in full accordance therewith

The Contractor shall have on file, for ready access and reference, a set of drawings indicating all work as actually installed incorporating in the same all changes and additions. Upon the termination of the Contract, he shall prepare a set of tracings indicating thereon the Electrical Work as actually and finally installed. These drawings shall be turned over to the Engineers.

The Contractor shall be responsible for keeping stocks of material and equipment stored at the premise in a neat and orderly manner. The exposed surfaces of wirings, conduit system or equipment which have become covered with dirt, plaster or other material during handling and construction shall be thoroughly cleaned by Contractor before such surfaces are prepared for final finish, painting or concealment within the building structure.

The Contractor shall employ skilled craftsmen experienced in installation of the types of electrical materials and equipment specified. Use specialized installation tools and equipment as applicable. Produce acceptance installation free of defects.

MATERIALS / TESTS

All materials to be installed shall be brand new and shall conform to specifications except as otherwise noted on the drawings. All materials where not specified shall be of the best of their respective kind. Samples of said material including its manufacturer's data shall be submitted for approval. Necessary tests on the installations shall be made by the Contractor in the presence of the Engineer. These tests shall include but not limited to ground test, performance test, phase sequence test, etc. Records of approved tests result shall be relayed to the Engineer in writing. This Contractor shall within ten (10) days after the award of the contract, submit a list of materials he proposes to use. All materials installed without prior approval shall be at the risk of the Contractor.

COORDINATION / GUARANTEES / SUSPENSION OR DELAY

The Contractor shall be familiar with the specifications of the other trades and coordinate with them thoroughly so that he can arrange his work and dispose his materials without interfering the work of other Contractors. The Contractor shall guarantee that the electrical systems shall be free from all defects of workmanship and of materials, and that it will remain so for a period of one year from the date of acceptance by the Engineer. Any remedy to correct defects deemed to be caused by such shall be made at the expense of the Contractor.

The Contractor shall not suspend or delay the work without justifiable cause. Subsequent delays shall be deemed as a sufficient cause for penalties or termination of contract in which the Engineer shall have the right to take-over the work and all materials on the site and make arrangements necessary to complete the work. It shall be the sole responsibility of the Contractor to ensure that the Electrical sub-contractor conducts coordination of his activities to other trades.

SLEEVES / INSERTS / CUTTING / PATCHING

The Contractor shall provide all openings, sleeves, also inserts in walls, floors, and beams as required for his work. All unused openings shall be grouted in. The Contractor shall do all patching requirements necessary and these shall be done so as to exactly match the surrounding area without the evidence of alteration or patching.

TEMPORARY LIGHT AND POWER

The Contractor shall make all arrangements and pay for the provisions of the necessary electrical power of the type and capacity required for the performance of the work of all trades engaged in the construction of the building.

CODES, INSPECTION, PERMITS AND FEES

The work under this contract is to be installed according to the requirements of the latest edition of the Philippine Electrical Code, the rules and regulations of the local authorities of Iloilo Commercial Port Complex (ICPC), Loboc, Lapaz, Iloilo City Electric Cooperative.

All necessary permits and electrical fees required for this work shall be obtained by and at the expense of the Contractor. The contractor shall furnish the Engineers and the Owner final certificate of electrical inspection and approval from the proper government authorities after completion of the work. The Contractor shall prepare all as-built and all forms and documents required by the approving authorities.

Power service application including drawings for the work shall be obtained by and at the expense of the Contractor. The Contractor shall comply with all requirements of the utility company regarding service applications.

ELECTRICAL CHARACTERISTICS

The electrical characteristics for this project shall be 400Y/230V, three phase (3Ø) wire, and 60Hz or as per system requirements as shown in the plan.

CLEANING UP

The Contractor shall remove all dirt, debris, and rubbish and waste materials caused by him in the process of his work. He shall also remove all tools, temporary power installation, scaffolding and surplus materials after completion and acceptance of work.

MATERIAL REQUIREMENTS

NAMEPLATES

Provide laminated plastic nameplates for each panel board, switch, and device. Each nameplate inscription shall identify the function and when applicable, the position. Nameplate shall be melamine plastic, 3.2mm thick, white with black center core. Surface shall be matte finish. Corners shall be square. Accurately align lettering and engrave into the black core. Minimum size of nameplates shall be 25mm x 38mm. Lettering shall be a minimum of 6mm, high normal block style.

EXECUTION

NAMEPLATE MOUNTING

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

INTERIOR WIRING SYSTEMS

SUBMITTALS

a. Shop Drawings: Submit for the following:

1. Location of panel boards and circuit breaker
2. Conduit support / hanger's installation drawing

b. Manufacturer's data: Submit for the following:

1. Circuit Breakers
2. Switches
3. Conduit and fittings (each type)
4. Device Plates
5. Insulated conductors
6. Utility / Junction boxes
7. Wall Receptacle, 3 Prong duplex convenience outlets with grounding

PRODUCTS

CONDUIT AND FITTINGS

a. Conduit shall be polyvinyl-chloride conduit (PVC) where specified, shall be heavy wall, high impact resistant Schedule 40, with factory made bends, couplings and fittings. PVC cement for joints shall be of the same brand as for the PVC pipe.

b. No conduits shall be used in any system smaller than 20mm (1/2") diameter electric trade size, nor shall have more than four (4) 90 degree bends in any one run and where necessary, pull boxes shall be provided as directed.

c. No wire shall be pulled into any conduit until the conduit system is completed in all details, in the case of concealed work until all rough plastering masonry has been completed, and in the case of exposed work until the conduit work has been completed in every detail.

d. The ends of all conduits shall have tightly plugged to exclude plaster, dust and moisture while the construction of the building is in progress. All conduits shall be reamed to remove all burrs.

OUTLETS, BOXES AND FITTINGS

a. All outlets whatever kind, for all system, there shall be provided a suitable fitting, which shall be either a box or other device especially designed to receive the type of fitting to be mounted thereon.

b. The Contractor shall consult with the Engineer as to the nature of the various fittings to be used before installing his outlet fittings, and shall conform strictly in the use of fittings, to the nature of the appliance to be mounted on them, so that the work, when the completed will be a finished design.

c. All outlets on concealed conduit work provide galvanized pressed steel outlet boxes on standard make. These boxes shall be in all cases standard and where such boxes are not available on the market, special boxes shall be secured by the Contractor at his owned expense. In general outlet boxes shall be at least 100mm diameter, 53mm deep and No. 16 minimum gauge.

JUNCTION AND PULL BOXES

a. Junction and pull boxes, of code gauge steel, galvanized shall be provided as indicated or as required for facilitating the pulling of wires and cables. Pull boxes as finished places shall be located and installed with the permission and to the satisfaction of the Engineer.

b. All junction and pull boxes on exposed conduit work shall be provided with hubs for threaded pipe entry and covers provided with neoprene gaskets.

WIRES AND CABLES

a. All wires shall be copper, soft-drawn and annealed, shall be 100% conductivity, shall be smooth and true of a cylindrical form and shall be within the actual size called for.

b. All wires and cables shall comply with the requirements of the Underwriters Laboratories, the ASTM and ICEA as they apply to the particular usage.

c. Wires and cables for power and lighting system shall be plastic insulated for 600 volts working pressure type "THHN/THWN-2" unless otherwise noted on plans or specified.

d. Cross-linked polyethylene (XLPE) insulated cables are used for power transmission and distribution, and are known for their electrical, thermal, and mechanical properties. XLPE cables are made of a single-stranded copper conductor wire insulated with XLPE plastic, which has a three-dimensional bond that improves its resistance to a number of things.

Here are some characteristics of XLPE cables:

- **Flame retardant**: XLPE insulation is a zero halogen thermoset that has flame retardant properties.
- **Temperature resistant**: XLPE cables can withstand extreme temperatures.
- **Chemical resistant**: XLPE cables are resistant to chemicals and other hazardous materials.
- **Durable**: XLPE cables are strong and durable.
- **Insulation**: XLPE insulation is resistant to oil and chemicals, even at high temperatures.

There are different types of XLPE cables, including:

- **Low voltage**

  Used in homes, offices, and industrial applications, with a voltage rating of up to 1kV
- **Medium voltage**

  Used in industries, commercial complexes, and residential areas, with a voltage rating of up to 35kV
- **High voltage**

  Used for long-distance power transmission and distribution, with a voltage rating of up to 500kV

e. Tag Marking

In general, branch circuit conductors and cables shall be properly marked by means of a printed tag taped on each wire indicating origin/load and or panel(s) where load is connected.

f. Splices and Termination Components

If applicable, for wire connectors and for insulating tape. Connectors for 5.5 mm^2 and smaller diameter wires shall be insulated, pressure-type in accordance with (twist-on splicing connector). Provide solderless terminal lugs on stranded conductors.

DEVICE PLATES

Provide, one piece device plates for outlets and fittings to suit the devices installed. Plates on unfinished walls and on fittings shall be of zinc-coated sheet steel or cast metal having round or beveled edges. Plates on finished walls shall be satin finish stainless steel or brushed –finished aluminum, minimum 0.03 inch thick. Screws shall be machine type with countersunk heads in a color to match the finish of the plate. The use of sectional type device plates will not be permitted. Plates installed in wet locations shall be sealed in gasket. Device plates for telephone and intercommunication outlets shall have a 3/8 inch bushed opening in center.

WALL SWITCHES AND PLATES

Wall switches in general shall be rated 10 amperes at 230 volts or with ampere and voltage ratings as required. Switches shall be flush mounting and of the rocker type, spring operated. The type of switches shall be tumbler operation and the color, plating and appearance of wall plates shall be as selected by the Engineer. Appropriate samples shall be submitted prior to purchase of wall switches and face plates.

WALL RECEPTACLE AND PLATES

a. Receptacle outlets shall be 15 amperes, 230 volts, 2 pole, 3 wire parallel slot, grounding type. Parallel slot outlet rated 15 amps. 125 v grounded type shall be acceptable for use with 230v system. Locking type and other special purpose outlets shall be as indicated in the plans.

b. Provide weather proof receptacle plate cover for each convenience receptacle outlet indicated as weatherproof.

PANELS AND CABINETS

a. Standard panels and cabinets, as much as possible shall be used and assembled on job. All panels shall be dead front construction, furnished with trims for flush or surface mounting. Cabinets shall be of code gauge steel with gutters at least 100mm wide and if necessary, it has to be made wider. The trim for all panels shall be finished in industrial grey enamel over a coat of rust inhibitor.

b. Lighting panels shall be equipped with branch circuit breakers as required and mains as noted on Plans or Panel Schedule.

c. Panel board main bus work shall be ampacity rated to equal or exceed overcurrent protective device immediately ahead of it. All buss work shall be properly secured to withstand available short circuit forces at the location.

d. Distribution panels shall be of the same type as lighting panels except equipped with one pole, two poles and three poles air circuit breakers of sizes, voltages ratings and interrupting capacity as called for on plans.

INDIVIDUAL BREAKERS

a. Provide individual circuit breakers where indicated on plans. Voltage ratings shall be suitable in each case of service application. Enclosures shall be General Purpose, NEMA type I, except where specifically noted on plans or assembled on panel cabinets.

All protective devices shall meet NEMA and U.L specifications. Short circuit rating shall be as indicated on the plan.

b. Circuit breakers shall consist of a quick-make, quick -break type entirely trip-free operating mechanism with contacts, arc-interrupter, and thermal magnetic trip unit for each pole, all enclosed in a molded-phenolic case. The thermal magnetic trip unit shall provide time-delayed overload protection, and in case of overload or short circuit current in any one pole the circuit trips instantaneously. Circuit breaker shall be trip indicating, when tripped position of breaker handle midway between "ON" and "OFF" positions.

c. All circuit breakers shall be bolt-on type unless noted otherwise.

d. All circuit breakers rated above 225 amps shall have interchangeable trip units. Unless otherwise specified, minimum interrupting rating for 230 volts circuit breakers shall be 10,000 amperes.

PANELBOARD BUSES

All bus panels shall be copper support bus bars on bases independent of circuit breakers. Main buses and back pans shall be designed so that breakers may be changed without machining, drilling, or lapping. Provide separate ground bus for connecting grounding conductors; bond to steel cabinet.

EXECUTION

INSTALLATION

a. Wiring Methods

Provide insulated conductors installed in conduits, except where specifically indicated or specified otherwise or required by PEC and NFPA to be installed otherwise. Provide insulated, equipment grounding conductor in feeder and branch circuits, including lighting circuits. Provide insulated, conductor for grounding conductors installed in conduits or raceways.

b. Conduit Installation

Unless indicated otherwise, conceal conduit within finished walls, ceilings, and floors. Keep conduit a minimum of 150mm away from parallel runs of flues and steam or hot water pipes. Install conduit parallel with or at right angles to ceilings, walls, and structural members where located above accessible ceilings and where conduit will be visible after completion of project. Run conduits in crawl space under slab as if exposed.

1. Where conduits rise through floor slabs, curved portion of bends shall not be visible above finish slab.

2. Conduit Support:

Conduit shall be supported by pipe straps, wall brackets, hangers, or ceiling trapeze. Fasten by wood screws to wood; by toggle bolts on hollow masonry units; by concrete inserts or expansion bolts on concrete or brick; and by machine screws, welded studs, or spring tension clamps on steelwork. Threaded C-clamps may be

used on rigid steel conduit only. Do not weld conduits or pipe straps to steel structures. Load applied to fasteners shall not exceed one-fourth proof test load. Fasteners attached to concrete ceilings shall be vibration resistant and shock resistant. Holes cut to depth of more than 40mm in reinforced concrete beams or to depth of more than 20mm in concrete joints shall not cut main reinforcing bars. Fill unused holes. In partitions of light steel construction, use sheet metal screws. In suspended-ceiling construction, run conduit above ceiling. Do not support conduit by ceiling support system. Spring-steel fasteners may be used for lighting branch circuit conduit supports in suspended ceilings in dry locations.

3. Changes in direction of runs with symmetrical bends or cast-metal fittings. Make field-made bends and offsets with hickey or conduit-bending machine. Do not install crushed or deformed conduits. Avoid trapped conduits. Prevent plaster, dirt or trash from lodging in conduits, boxes, fittings, and equipment during construction. Free clogged conduits of obstructions.

4. The Contractor shall install pull wires in empty conduits in which wire is to be installed by others. The pull wire shall be 2.0mm^2 zinc- coated steel or plastic having not less than 91 kgs tensile strength. Leave not less than 300mm of slack at each end of the pull wire.

5. Conduit Installed in Concrete Floor Slabs

   Locate so as not to adversely affect structural strength of slabs. Install conduit within middle one-third of concrete slab. Do not stack conduits. Space conduit horizontally for at least three diameters, except in cabinet locations. Curved portions of bends shall not be visible above the finish slab. Increase slab thickness as necessary to provide minimum 25 mm cover over conduits. Where embedded conduits cross expansion joints, provide suitable watertight expansion fittings and bonding jumpers. Conduit larger than 25mm trade size shall be parallel with or at right angles to main reinforcement; when at right angles to the reinforcements, the conduit shall be closed to one of the supports of the slab.

6. Fasten conduits to sheet metal boxes and cabinets with two locknuts where required by PEC and NFPA 70, where insulated bushings are used, and where bushing cannot be brought into firm contact with the box; otherwise, use minimum single locknut and bushing. Locknuts shall have sharp edges for digging into wall of metal enclosures. Install bushings on ends of conduits, and provide insulating type where required by PEC and NFPA 70.

7. Flexible Connection:

   Provide flexible connection of short length, 1.8 meters maximum for recessed and semi-recessed lighting fixtures.

c. Boxes, Outlets, and Supports

Provide boxes in wiring or raceway systems wherever required for pulling of wires, making connections, and mounting of devices or fixtures. Boxes for metallic raceways shall be cast-metal, hub-type when located in wet locations, when surface mounted on outside of exterior surfaces, when installed exposed up to 2.1meters above interior floors and walkways, or when installed in hazardous areas. Boxes in other locations shall be sheet steel, except that aluminum boxes may be used with aluminum conduit. Each box shall have the volume required by PEC and NFPA 70 for the number of conductors enclosed in the box. Boxes for mounting lighting fixtures shall not be less than 100 mm2 or octagonal, except that smaller boxes may be installed as required for fixture configurations as approved. Boxes for use in masonry-block or tile walls shall be square-cornered, tile-type, or standard boxes having square-cornered, tile-type covers. Provide gaskets for cast-metal boxes installed flush with

outside of exterior surfaces. Provide separate boxes for flush or recessed fixtures when required by fixture terminal operating temperature. Fixtures shall be readily removable for access to boxes unless ceiling access panels are provided. Support boxes and pendants for surface-mounted fixtures on suspended ceilings independently of ceiling supports, or make adequate provisions for distributing load over ceiling support members. Fasten boxes and supports with wood screws on wood, with bolts and expansion shields on concrete or brick, with toggle bolts on hollow masonry units, and with machine screws or welded studs on steel. In open overhead spaces, cast boxes threaded to raceways need not separately supported except where used for fixture support; support sheet metal boxes directly from building structure or by bar hangers. Where bar hangers are used, attach bar to raceways on opposite sides of box, and support raceway with approved type fastener maximum 600mm from the box. When penetrating reinforced concrete members, avoid cutting reinforcing steel.

1. Boxes for use with raceway systems shall be minimum 40mm deep, except where shallower boxes required by structural conditions are approved. Boxes for other than lighting fixture outlets shall be minimum 100mm2, except that 100 by 50mm boxes may be used where only one raceway enters outlet.

2. Pull Boxes:

   Pull boxes shall be constructed of not less than the minimum size required by PEC and NFPA 70 of code-gauge aluminum or galvanized sheet steel, except where cast-metal boxes are required in locations specified herein. Boxes shall be furnished with screw-fastened covers. Where several feeders pass through common pull box, the Contractor shall tag the feeders to indicate clearly electrical characteristics, circuit number, and panel designation.

d. Mounting Heights

The Contractor shall mount panelboards, and circuit breakers, and main disconnecting panel so the height of the operating handle at its highest position is maximum 1.8 meters above floor. Mount lighting switches 1.4 meters above finished floor, receptacles 300mm above finished floor and other devices. The Contractor shall measure mounting heights of wiring devices and outlets to center of device or outlet.

e. Conductor Identification

Provide conductor identification within each enclosure where tap, splice, or termination is made.

f. Splices

Make splices in accessible locations. Make splices in conductors 5.5 mm^2 and smaller diameter with insulated, pressure-type connector. Make splices in conductors 8.0 mm^2 and larger diameter with solderless connector, and cover with insulation material equivalent to conductor insulation.

g. Covers and Device Plates

Install with edges in continuous contact with finished wall surfaces without use of mats or similar devices. Plaster fillings are not permitted. Plates shall be installed with alignment tolerance of 3mm. Use of sectional-type device plates are not permitted. Plates installed in wet areas must be gasketed.

h. Electrical Penetrations

Openings around electrical penetrations through fire resistance-rated walls, partitions, floors, or ceilings shall be sealed to maintain fire resistive integrity as tested per ASTM E 814.

i. Grounding and Bonding

In accordance with PEC and NFPA 70. Ground all exposed, noncurrent-carrying metallic parts of electrical equipment, metallic raceway systems, grounding conductor in metallic and non-metallic raceways, and conductor of wiring systems. Make ground connection to driven ground rods on exterior of building. Where ground fault protection is employed, ensure that connection of ground does not interfere with correct operation of fault protection.

1. Grounding Conductor

   Provide insulated, equipment grounding conductor in feeder and branch circuits, including lighting circuits. Grounding conductor shall be separate from electrical system neutral conductor. Provide insulated, conductor for grounding conductors installed in conduit or raceways.

2. Resistance

   Maximum resistance-to-ground of grounding system shall not exceed 10 ohms under normally dry conditions. Where the resistance obtained exceeds 10 ohms, contact the Engineer for further instructions.

FIELD QUALITY CONTROL

Furnish test equipment and personnel and submit written copies of test results. Give the Engineer five (5) working days notice prior to each test.

a. Devices Subject to Manual Operation

Each device subject to manual operation shall be operated at least five times, demonstrating satisfactory operation each time.

b. Test on 600 volt wiring

Test 600 volt wiring to verify that no short circuits or accidental grounds exist. Perform insulation resistance tests on wiring No. 14mm^2 (6 AWG) and larger diameter using instrument which applies voltage of approximately 500 volts to provide direct reading of resistance. Minimum resistance shall be 25,000 ohms.

c. Grounding System Test

The Grounding system shall be tested to ensure continuity and resistance to ground is not excessive. Test each ground rod for resistance to ground before making connections to rod; tie grounding system together and test for resistance to ground. Make resistance measurements in dry weather, not earlier than 48 hours after rainfall. Submit written results of each test to the Engineer and indicate location of rods as well as resistance and soil conditions at the time measurements were made.

INTERIOR LIGHTING

SUBMITTALS

Data, shop drawings showing mounting heights, and reports shall employ the terminology, classifications, and methods prescribed by the IES Lighting Handbook, as applicable, for the lighting system specified.

a. Manufacturer's Data

1. T-8 LED Tube Light 21 watts daylight 4ft industrial housing aluminum reflector
2. Frosted LED Downlight , 20 watt daylight SMD type
3. Exterior Wall Lamp, Deluxe 15 watt, daylight

PRODUCT

T-8 LED FLUORESCENT TUBE

1. The T8 LED Tube light Industrial – designed as a retrofit for the standard fluorescent lamp fittings.

   It has better energy efficiency and long service life compared to its predecessor. As a result, this turns into cost savings.

   Powered by light emitting diodes and circuitry, another advantage is that it does away with dangerous chemicals found in your typical fluorescent tubes making it nonhazardous and likewise Eco-friendly.

FROSTED LED DOWNLIGHT

2. The Frosted LED Downlight 20W SMD provides efficient lighting in compact spaces, with zero heat output. Ideal for Space-Saving Solution and Downlight. Perfect for stores, museums, restaurants, and more.

   Frosted LED Downlights provide strong efficient lighting in a compact space to highlight certain areas of interest, older iterations that are halogen based have been the likely choice for this type but they produce a great deal of heat. Also, frosted LED Downlights have extra bright, virtually zero or minimal thermal footprint and has unparalleled energy efficiency. This makes it cut out for our households, schools, theaters, and places where you want excellent lighting but need to stay at a comfortable temperature.

EXTERIOR WALL LAMP, DELUXE 15 WATT DAYLIGHT

3. LED Wall Lamp provides a beautiful touch as well as a functional necessity to your hallway or walkway, garden walls, or even part in your residential front line lighting. This has been in style since the inception of outdoor lighting.

   The LED wall lamps can do a lot more, not only provide illumination and safety; and they also create an air of sophistication and elegance throughout your home. Incredibly versatile.

RECESS AND SURFACE MOUNTED FIXTURES

The Contractor shall install the type of materials as shown on the plan.

EXECUTION

INSTALLATION

The electrical installation of interior lighting shall conform to the requirements of the approved plan.

GROUNDING

Ground non-current-carrying parts of equipment as specified in "Interior Wiring Systems." Where the copper grounding conductor is connected to a metal other than copper, provide specially treated or lined connectors suitable for this purpose.

FIELD TESTS

The Contractor will provide electric power and apparatus / instruments required and carry out the field tests.

a. Operating Test

Upon completion of the installation, conduct an operating test to show that the equipment operate in accordance with the requirements of this section.

b Insulation Resistance Test

Perform as specified in "Interior Wiring Systems", both before and after connection of fixtures and equipment.

c. Ground Resistance Tests
Perform as specified in "Interior Wiring System."

ITEM 19 : GROUNDING SYSTEM AND LIGHTNING PROTECTION

GENERAL

REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

1. American National Standards Institute (ANSI)

   ANSI C135.30 (1988) Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction

2. Institute of Electrical And Electronics Engineers (IEEE)

   IEEE Standard 81 (1983) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Potentials of a Ground System

3. National Fire Protection Association (NFPA)

   NFPA 70 (2007) National Electrical Code
   NFPA 780 (2007) Lightning Protection Code

4. Underwriters Laboratories (UL)

   UL Elec Const Dir (2007) Electrical Construction Materials Directory
   UL 96 (2005) Lightning Protection Components
   UL 96A (2007) Installation Requirements for Lightning Protection Systems
   UL 467 (2007) Grounding and Bonding Equipment

5. Institute of Integrated Electrical Engineer (IIEE)

   PEC (2002) Philippine Electrical Code

6. Philippine National Standard (PNS)

   BS (2002) Bureau of Standard

RELATED REQUIREMENTS

"Electrical General Requirements," applies to this section with additions and modifications specified herein.

1. System Requirements

   Materials shall consist of standard products of a manufacturer regularly engaged in production of lightning protection systems and shall be manufacturer's latest UL approved design. Lightning protection system shall conform to PEC, NFPA 70, NFPA 780, UL 96 and UL 96A.

SUBMITTALS

1. Shop Drawings

Overall lightning protection system each major component

2. Test Reports

Grounding system test
Lightning protection system inspection

3. Certificates

UL listing or label

QUALITY ASSURANCE

In each standard referred to herein, consider the advisory provisions to be mandatory, as though the word "shall" has been substituted for "should" wherever it appears.

1. Installation Drawings

a. Submit installation shop drawing for the overall lightning protection system. Drawings shall include physical layout of the equipment, mounting details, relationship to other parts of the work, and wiring diagram.

b. Submit detail drawings for each major component to include manufacturer's descriptive and technical literature, catalogue cuts, and installation instructions.

2. UL Listing or Label

Submit proof of compliance, label of acceptable evidence. In lieu of label or listing, submit written certificate from an approved, nationally recognized testing organization equipped to perform such services, stating that items have been tested and conform to requirements and testing methods of Underwriters Laboratories.

SITE CONDITIONS

Contractor will become familiar with details of the work, verify dimensions in the field, and advise the Engineer of discrepancies before performing work. Deviations from contract drawings will not be made without prior approval of the Engineer.

MATERIAL REQUIREMENTS

MATERIALS

Do not use a combination of materials that forms an electrolytic couple of such nature that corrosion is accelerated in presence of moisture unless moisture is permanently excluded from the junction of such metals. Where unusual conditions exist which would cause corrosion of conductors, provide conductors with protective coatings or oversize conductors. Where mechanical hazard is involved, increase conductor size to compensate for hazard or protect conductors by covering them with or tubing made of nonmagnetic material.

1. Main and Bonding Conductors

   NFPA 780 and UL 96

2. Copper

   Provide copper conductors on non-metallic stacks that do not weigh less than 144.83 kg per 300 meters, and provide cable such that the size of any strand in the cable is not less than $2mm^2$.

COMPONENTS

1. Air Terminals

   Early Streamer Emission, ESE, Lightning Conductor
   Lightning Strike Counter, Starting Threshold from 1 to 100kA or more 8/20 wave, 3 digits analog display, IP65 Protection and 3-5 meter Pole Mast 2" G.I. sch 40 with adapter , welding support and paint.

   Provide terminals in accordance with UL 96. Support air terminals by suitable brace, with guides, not less than one-half the height of the terminal. (20mmØ x 1000 m long)

2. Ground Rods

   Provide ground rods made of copper-clad steel conforming UL 467. Provide ground rods that are indicated on the approved plan. Do not mix ground rods of copper-clad steel, stainless steel, galvanized ferrous, or solid copper on the job. (20mmØ x 3.0m long)

3. Connections and Terminations

   Provide connectors for splicing conductors that conform to UL 96, class as applicable. Conductor connections can be made by clamps or welds (including exothermic). Provide style and size connectors required for the installation.

4. Connector Fittings

   Provide connector fittings for "end-to-end", "Tee", or "Y" splices that conform to NFPA 780.

5. Lightning Protection Components

   Provide bonding plates, air terminal supports, clips, and fasteners that conform to UL 96 classes as applicable.

EXECUTION

INTEGRAL SYSTEM

Lightning protection system consists of air terminals, down conductors, ground connections, grounding electrodes and ground loop conductor. Electrically interconnect lightning protection system to form the shortest distance to ground. Do not use non-conducting parts of the structure as part of the building's lightning protection system. Conductors are required to be in protective sleeves.

1. Air Terminals

Air terminal design and support conforming to NFPA 780. Rigidly connect terminals to, and make electrically continuous with, down conductors by means of pressure connectors or crimped joints of T-shaped malleable metal. Provide pressure connector or crimped joint with a dowel or threaded fitting to connect ground rod conductor with air terminal. Set air terminals at ends of structures not more than 610mm from ends of ridges. Where non-metallic spires, is present, mount air terminal to the side. In addition, where spires project more than 3050mm above the building, continue conductor from air terminal to nearest down conductor securely connect thereto.

2. Down Conductors

Make down conductors electrically continuous from air terminals to grounding electrodes. An equally and symmetrically spaced down conductors about the perimeter of the structure. Protect conductors where necessary, to prevent physical damage or displacement to the conductor.

a. Ground Connections

Securely connect conductor forming continuations of down conductors from structure to grounding electrode in a manner to ensure electrical continuity between the two. Provide clamp type connections or welds (including exothermic) for continuation. Attach down conductor to ground rods by welding including exothermic, brazing, or clamping. Provide clamps suitable for direct burial. Protect ground connection from mechanical injury. In making ground connections, take advantage of all permanently moist places where practicable, although avoid such places when area is wet with waste water that contains chemical substances, especially those corrosive to metal.

b. Grounding Electrodes

Provide grounding electrode for down conductor. Extend driven ground rods into the existing undisturbed earth for a distance of not less 3050mm. Set ground rods less than 610mm nor more than 3050mm, from the structure. After the completed installation, measure the total resistance to ground using the fall-of-potential method described in IEEE Standard 81. Maximum resistance of a driven ground rod shall be 10 ohms, under normally dry conditions. Make connections between ground conductors and electrically ground continuous.

FIELD QUALITY CONTROL

1. Grounding System Test

Test the grounding system to ensure continuity and that resistance to ground is not in excess of 10 ohms. Test the ground rod for resistance to ground before making connections to the rod. Tie the grounding system together and test for resistance to ground. Make resistance measurements in dry weather, not earlier than 48 hours after rainfall. Include in the written report: locations of ground rods, resistance, and soil conditions at the time that measurements were made. Submit results of each test to the Engineer.

2. Lightning Protection System Inspection

Make visual inspections to verify that there are no loose connections which may result in high resistance joints and that conductor and system components are securely fastened to their mounting surfaces and are protected against accidental mechanical displacement.