PETROGUARDIAN™ LLC

LIGHTNING PROTECTION SYSTEM DEVELOPMENT STUDY

PREPARED FOR

PREPARED BY: HARSHUL GUPTA | DIRECTOR OF ENGINEERING SERVICES
APPROVED BY:

Date	Revision Number	Executed by	Approved by	Section Revised
11.19.16	0	HG	TC	

SECTION	DESCRIPTION	PAGE NUMBER
1	**INTRODUCTION**	
1.1	OBJECTIVES	3
1.2	RISK OF LIGHTNING RELATED DAMAGE	3
2	**BACKGROUND ON LIGHTNING**	5
2.1	HAZARDS OF LIGHTNING HAZARDS	6
2.2	PROTECTION	6
3	**SURVEY DATA AND RECOMMENDATIONS**	
3.1	MCC BUILDING	7
3.2	POWER GENERATOR & ATS	8
3.3	CATHODIC PROTECTION PANEL	8
3.4	STORAGE TANK	8
3.5	LACT	9
3.6	GATHERING MANIFOLD	9
3.7	TRUCK OFF-LOADING AREA	10
3.8	SOIL RESISTIVITY MEASUREMENTS	11
3.9	CLAMP ON METER READING DATA	11
3.10	PUMP STATION	12
4	**BILL OF MATERIAL**	
4.1	BOM FOR STORAGE TERMINAL	13
4.2	MATERIAL BREAKUP PER LOCATION AT TERMINAL	14
4.3	BOM FOR PUMP STATION	15
4.4	SUMMARY OF COST	16
5	**TESTING, MAINTENANCE AND INSPECTION**	
5.1	INSPECTION	17
5.2	FREQUENCY OF INSPECTION	17
5.3	PREREQUISITES	17
5.4	ANNUAL INSPECTION CITERIA	18
5.5	TESTING CRITERIA	19
6	**PERSONNEL SAFETY**	
6.1	PLANNING FOR PERSONNEL WARNING	20
6.2	GENERAL GUIDANCE FOR OUTDOOR WORKERS	21
7	**ATTACHMENTS**	
	RECOMMENDED MATERIAL DATA SHEETS	

INTRODUCTION

Objectives

The primary focus of this site survey is to analyze the reasons for failure of the below noted electronics and develop a material recommendation to protect electrical, electronic, control and measurement devices at the [redacted] Similar recommendation are to be developed for [redacted] station based on the layout and equipment at [redacted]

Electronic Equipment Damaged

1. Tank Level Transmitter
2. Pressure Transmitter and PLC cards on LACT units
3. Pressure Transmitter, PLC Cards and HMI on Truck offloading LACT Units

The fundamental principle in protection of life and property against lightning is provision of a means by which lightning discharge can enter or leave earth with no resulting damage or loss to the facility, its occupants and operating electronic equipment. A low-impedance path to ground is necessary to ensure this continuous discharge and to attempt to manage the path of currents with minimum undesirable current flow through building materials, equipment or personnel.

A low impedance path to ground for lightning discharges is achieved by providing strike termination devices on the high point of the structure, multiple interconnecting conductors, surge protection devices on electronics and a ground electrode system.

The requirements outlined within the most recent NFPA 780 and IEC 62305 represent the state of art in lightning protection for facilities world-wide. The sections IEC 62305-3 and IEC 62305-4 represent the requirements for structural lightning protection and protection of electrical and electronic systems respectively.

Risk of Lightning related damage

All remote facilities are exposed to four primarily risks of lightning related damage. The level of risk on each of the structures within a facility will vary based on their physical dimensions and the level of automation and control systems within the structure. Following are the four risks:

1. **Direct Lightning Strike to structure**: Structures with high risk of direct lightning strikes are recommended to furnish a structural lightning protection system comprising of air terminals and suitable grounding systems in compliance to NFPA 780 and IEC 62305. The lightning air terminals become the preferred point of lightning strike and thus provide the protection to the structure. For structures with flammable material, the lightning protection system installed are recommended to have two unique properties – if installed on the structure, the air terminals should be isolated from the structural chassis by using a High Voltage insulated lightning conductor to keep the charge off the chassis OR the lightning protection system should be installed away from the structure keeping the spacing adequate to avoid flash over. The goal of isolation is to minimize risk of ignition. The Air Terminals are placed such that the structure being protected is covered under a defined “Zone of Protection”.

2. **Direct Lightning Strikes on power transmission line**: The shield wire on the power transmission lines is most hit by lightning strikes. The change in electromagnetic field around the line cables induces lightning currents that frequently travels to the loads feeding off the power transmission line. These currents have the capability to along the power distribution network of a facility and cause damage to electrical and

electronic loads. A staged lightning generated surge protection system is recommended to minimize the damage that an induced lightning current may cause.

3. **Induced lightning currents on power and control cables due to nearby lightning strikes**: The frequent change in electromagnetic field associated with nearby lightning strikes and lightning currents travelling on the ground surface induce lightning impulse currents within the power and control cables that may be overhead or underground on a facility. Field instruments, control panels and power distribution panels generally fall in this category. A staged lightning generated surge protection system is recommended to minimize the damage that an induced lightning current may cause.

4. **Induced lightning voltages on ground reference due to nearby lightning strikes:** The lightning currents travelling on the ground surface due to nearby lightning strikes induce a ground potential rise on each of the ground references they flow across. Field instruments and control panels are mostly damaged due to this source of risk. A staged lightning generated surge protection system is recommended to minimize the damage that an induced lightning current may cause.

At [redacted], we will tabulate the type of risk and the level of risk (Low/ High) to facilitate decision on implementing protection measures.

	Risk level of Lightning related damage based on source of lightning			
Structures	1	2	3	4
MCC Building	Low	High	High	High
ATS	Low	Low	High	High
CP Panels	Low	Low	High	High
Storage Tanks	High	Low	Low	High
Tank Battery	High	High	High	High
Gathering manifold	High	High	High	High
Truck Off Loading	High	High	High	High
Remote Pump Stations	High	High	High	High

Source of Lightning

1. Direct Lightning Strike to structure
2. Direct Lightning Strikes on power transmission line
3. Induced lightning currents on power and control cables due to nearby lightning strikes
4. Induced lightning voltages on ground reference due to nearby lightning strikes

The recommendations that follow provide protection measures for the highlighted section of the above risk analysis table.

Background on Lightning

Lightning is an atmospheric discharge of electricity that typically occurs during thunderstorms. A bolt of lightning can travel at a speed of 136,000 miles per hour (220,000 kilometer per hour) and can reach temperatures approaching 54,000 degrees Fahrenheit (°F) [30,000 degrees Celsius (°C)], hot enough to fuse soil or sand into glass.

Over 16 million lightning storms occur every year. In any U.S. geographical location, lightning storms occur as few as five times or as many as 100 times per year. A single lightning flash (event) will typically consist of from one to twenty or more individual current strokes with the average being between four and seven.

Thunderstorms are relatively uncommon along much of the West Coast of the United States, but they occur with greater frequency in the inland areas, particularly the Sacramento Valley and San Joaquin Valley. Furthermore, inspring and summer, they occur nearly daily in certain areas of the Rocky Mountains. In the Northeast, storms take on similar characteristics and patterns as the Midwest, only less frequently and severely. Probably the most thunderous region outside of the Tropics is Florida. During the summer, violent thunderstorms are an almost daily occurrence over central and southern parts of that state.

Each year, thousands of industrial, commercial, residential, and other properties are damaged or destroyed by lightning. It accounts for more than a quarter billion dollars in property damage annually in the United States. Lightning is responsible for more deaths and property loss than tornadoes and hurricanes combined, and of these violent forces of nature, lightning is the only one where protection can be economically provided.

Rather than describing the magnitude of an “average” lightning stroke, it is easier to give ranges for the various parameters. The important part of a lightning flash with regard to the resulting damage is the return stroke. The current in this return stroke ranges from about 2,000 amperes to about 400,000 amperes. Its distribution of values is a “log-normal” distribution, where:

- one percent of strokes exceeds 400,000 amperes.
- ten percent of strokes exceed 80,000 amperes.
- fifty percent of strokes exceed 28,000 amperes.
- ninety percent of strokes exceed 8,000 amperes.
- ninety-nine percent of strokes exceed 3,000 amperes.

The current in most ground flashes emanates from negatively charged cells in the thundercloud and the resulting flash current is a negative flow. Occasionally, positive strokes occur. Regardless of the polarity, the current flow is unidirectional for each segment of potential degradation. Typical rise time and decay time for a negative flash are less than 10 milliseconds (ms) and 100 ms, respectively. Rise time for a positive flash is greater. Flashes are typically comprised of multiple strokes that, individually, conform to the description for a single stroke, but may range from 50 to 100 ms apart.

Hazards associated with Lightning

Lightning hazard to facilities and personnel can take many forms:

- Electrical current produced by a voltage gradient resulting from a lightning flash to a facility can initiate physical damage, fires, equipment damage or injury to personnel.
- Surface flashover or arcing of generated electrical current between conductive surfaces not in equilibrium can initiate damage directly by the heat, sparks, and molten metal generated by the arc.
- Side-flash is an electrical spark caused by differences of potential that occurs between conductive metal bodies or between conductive metal bodies and a component of the Lightning Protection System (LPS) or earth electrode system during a lightning flash. Side-flash presents direct and indirect hazards to facilities, hazardous environments and personnel both internal and external to the facility. The direct hazard is the electrical energy transferred from the structure or its LPS to building components or personnel. Indirect hazards are the heat and the electromagnetic fields generated by the electrical energy which can cause concrete to spall or combustible materials to ignite. Electromagnetic fields could induce electrical currents on or in the building or equipment.
- Generated arcing can cause damage or fires in electrical fixtures and equipment.
- Lightning could initiate a fire involving combustible materials inside the facility.
- Spalling of concrete or other surface materials generated by the heat of the current flowing through the structural components of the facility can physically damage equipment in the facility. Such spalling may also present an injury risk to personnel.
- Lightning can affect support systems such as automation and control, communication, CATV, fire protection, HVAC, and security systems.
- Lightning can reach a structure not only by direct strike, but also indirectly by coupling to conductors or conductive utility services that penetrate the structure.
- Lightning discharges will produce electromagnetic pulses that can be coupled onto conductors servicing the structure. These induced surges can be adequate to cause dangerous over-voltages, resulting in fires or damage to critical electrical and electronic hardware. Surge protection devices protect facilities against induced surges on power, communication, data and process control lines, and any other electrically conductive objects entering or exiting the facilities

Protection

When lightning follows higher impedance paths, damage may be caused by heat and mechanical forces generated during the discharge process. Most metals, being good electrical conductors, are relatively unaffected by either heat or mechanical forces if they are of sufficient size to carry the expected magnitude of current. The metal path should utilize isolated continuous lightning conductors from each strike termination device providing uninterrupted downward connections with ground electrodes.

Protection from lightning-induced hazards can best be achieved by a properly designed and installed LPS meeting the requirements of NFPA780 and IEC 62305. An LPS consists of, as a minimum, strike termination devices (air terminals) , low impedance paths to ground, an earth electrode system and surge protection devices on electrical and electronic equipment.

SURVEY DATA COLLECTED

MCC Building

The MCC building is primarily at risk of induced lightning surges arising from lightning strikes on power transmission lines and from nearby lightning strikes that result in the ground potential rise . The following panels within the MCC building will require a suitable protective device.

Recommendations:

Installation of UL Type 1/ IEC Class 1 lightning current arrester which is UL approved and for up to 30 kA SCCR shall minimize the risk of losing power and also minimize the risk of distribution of lightning current to downstream equipment. The protection device will be provided within a NEMA rated box integrated with a breaker and shall be installed as a load to each of the panel. The protection device can be connected directly to the panel bus or to a spare breaker on the panel. The connection leads are to be kept as straight and short as possible. These devices activate only when they sense a lightning impulse voltage or current or both on the power bus. Effectiveness of these devices is based on their speed of reaction and let through voltage capacity.

Suitable protection devices are to be installed on the following panels.

- *MSWB*
- *Pump 101 VFD Panel*
- *Pump 102 VFD Panel*
- *MOV Panel*
- *Power Panel for Control valves*
- *LP Panel for Street Lighting and Cathodic protection panels*

The control room for the [redacted] is located within the MCC building as well. The three most important control panels that are critical to the operation and revenue for [redacted] are part of this control room.

PLC Control panel
OMNI – Manifold Area
OMNI – LACT Units

The PLC is powered through a 120VAC source that is generally provided from a UPS. The risk of induced surges within the 120VAC circuit are minimal from the source, however, the 120VAC line can get influenced via a ground potential rise caused by induced currents from control equipment shield wire. A surge on the 120VAC line can damage the PLC and the DC power source. A Phoenix surge protection devices (PT2-PES) was found installed to protect the 120VAC distribution. The unit was either incorrectly installed or had completed its lifecycle and should be replaced with the recommended unit.

Field instrumentation and control equipment are connected to these panels via 4-20mA 24VDC pair of cables. The shield of each of these pairs are terminated to the ground bus within these panels. Lightning induced currents are expected to enter these control panels on the copper pair and shield wire.

Recommendations:

- *Appropriate UL Type 1/ IEC Class I surge protection devices suitable for 24VDC 4-20mA circuits must be installed on the field circuit landing Terminal Strip. The unprotected and protected pairs must be routed away from each other to avoid mutual coupling.*

- *UL Type 2/ IEC Class II surge protection devices must be installed at the 120VAC distribution terminal and 24VDC distribution terminal.*
- *Backup data transfer is on RS485 links that connect the PLC to the radio, truck offload area and manifold area. Suitable surge protection devices must be installed on each of these links between the PLC and field.*
- *Install N connector type DC to 5.8 GHz 50 ohm resistance Surge protector for Radio Antenna*

Power Generator Automatic Transfer Switch

The operation of the ATS during a power outage is critical to the control system of [redacted] Incidents of lightning in the area can potentially damage the electronics involved in power source detection and automatic switching of power source. Though no damage to ATS was reported so far, installation of protection measures are recommended.

Recommendation:
Installation of UL Type 1/ IEC Class 1 lightning current arrester which is UL approved for up to 30 kA SCCR is recommended to minimize the risk of losing power switching electronics within the ATS.

Cathodic protection panels

The continuous operation of Cathodic Protection circuits is important for the corrosion protection system installed on storage tanks. Maintenance personnel have experienced instances when the main power breaker tripped during lightning events within the CP panels. No damage to the power rectifiers were reported. Review of the CP panels showed that there were two CP Panels – External and Internal. A 120VAC Surge protection Devices was found installed on the External panel. The internal panel has both 120VAC surge protection devices and a 75VDC surge protection device at the output of the rectifier. The installed surge protection devices had no indicators to show if they were in operation. The manufacturer of these surge protection devices has not defined the class of these Surge protection devices so it is difficult to comment on their effectiveness.

Recommendations:
It is recommended that the suitable SPDs on both External and Internal CP Panel be replaced to UL Type 1/ IEC Class 1 SPD for 120VAC circuit and a UL Type 2/ IEC Class II Surge Protection Devices for 24VDC circuit. Both devices must have visual indicators.

Storage Tanks

There are a total of 9 storage tanks at the facility. All 9 storage tanks are at a high risk of direct lightning strikes. No case of direct strike or any damage associated with a direct lightning strike was reported so we will exclude any recommendations for structural lightning protection in this study. Loss of Level Transmitter and Level Detector has been reported. The measuring the transmitting electronics is powered by a solar power system installed on the tanks. The DC power source references the tank grounding system. Lightning induced ground potential rise is probably the major cause of electronics failure on the storage tank. Following are the electronics that require protection:

- Solar Battery Charger and 12VDc to 24VDC power converter
- Temperature Transmitter
- Level Transmitter
- Level Detector
- Radar Sensor
- Radar Sensor Remote Monitor

Recommendations:

- *Install a 24VDC SPD Ex rated with Life Check for protecting 2 pairs in intrinsically safe measuring circuits. Two of these will be installed within the solar radio enclosure to protect the 24VDC power connections to ILA, TIT and LT.*
- *Install a 24VDC SPD Ex rated with Life Check for protecting 4 earth potential free single line with common reference potential in intrinsically safe measuring circuits. Two of these will be installed within the solar radio enclosure to protect the 24VDC circuits to LT and LI.*
- *Install 24VDC SPD ex rated directly to the field instruments ILA, TIT, LT and LI for protecting measuring and power supply circuits*
- *Reference Drawings: TX-MIDL-ELIN-360.1; TX-MIDL-ELIN-360.2*

LACT Skids

LACT skids are located near the 3 smaller storage tanks. The instrumentation and control system on the LACT has experienced downtime and damages during lightning events. There is minimal danger of direct strikes on the LACT skids. The reported damages are most probably from nearby lightning strikes and resulted ground potential rise.

Recommendation:

- *Install 24VDC SPD ex rated directly to the field instruments AIT, TIT, PIT, Micromotion 2700 (DIT, YIT, FIT), Lact Pump Starter, ZIC 1311 and ZIC 1312 for protecting field instruments.*
- *Install a 24VDC SPD with Life Check for protecting 2 pairs in intrinsically safe measuring circuits. These will be installed within the PLC cabinet on AIT, TIT, PIT, Micromotion 2700 (DIT, YIT, FIT), ZIC 1311 and ZIC 1312. These provide protection for the PLC control cards.*
- *Install a 24VDC SPD with Life Check for protecting 4 earth potential free single line with common reference potential in intrinsically safe measuring circuits. These will be installed within the PLC cabinet on Lact Pump Starter control terminals. These provide protection for the PLC control cards.*
- *Install a 120VAC and 24VDC power line protectors within the PLC panel on the respective power distribution terminals. This provides protection to the PLC and 24VDC power source module.*
- *Install a 277/480VAC Type 1 SPD on the pump starter panel. This provides protection to the pump motor.*
- *Reference Drawings: TX-MIDL-ELIN-360.7; TX-MIDL-ELIN-360.8*

Gathering Manifold

The gathering manifold area has no tall structures. The risk of direct lightning strike is minimum. Loss of electronic circuits in the PLC and loss of field instruments can be attributed to near-by strikes and resulting induced voltages in the ground reference voltage and induced current in control cables.

Recommendations:

- *Install a 277/480VAC Type 1 SPD on the MOV power panel. This is to provide protection to the electric actuators on MOV.*
- *Install a 120VAC Type 1 SPD on the 120/240VAC lighting panel on each of the two 120V supply lines.*
- *Install 24VDC SPD ex rated directly to the field instruments for protecting measuring and power supply circuits – 4 Pressure Transmitter and 2 Flow Meters*
- *Install a 120VAC and 24VDC power line protectors within the PLC panel on the respective power distribution terminals.*
- *Install 10 units of 24VDC SPD with Life Check for protecting 1 pair in intrinsically safe measuring circuits within the PLC panel.*

Truck Off loading

The power panel for the Truck off-loading area is exposed to both induced current in the power cables and induced voltages on ground reference. Surges on these panels could damage the soft starters and damage the motors on the distribution pump.

The LACT located at the truck off-loading area are exposed to the similar risks as the LACT located near the Tank battery. The recommended protection for the field instrumentation and control panel will remain the same as for the LACT at storage tanks.

Recommendations:

- *Install a suitable Type 1 surge protection device is recommended on each of the 277/480VAC power panels for: Sump 301; LACT1101; LACT 1001; LACT901; LACT801; LACT701; LACT601 and 480VAC Distribution panel*
- *Install 24VDC SPD ex rated directly to the field instruments AIT, TIT, PIT, Micromotion 2700 (DIT, YIT, FIT), LACT Pump Starter, ZIC 1311 and ZIC 1312 for protecting field instruments.*
- *Install a 24VDC SPD with Life Check for protecting 1 pair in intrinsically safe measuring circuits. These will be installed within the PLC cabinet on AIT, TIT, PIT, Micromotion 2700 (DIT, YIT, FIT), ZIC 1311 and ZIC 1312.*
- *Install a 24VDC SPD with Life Check for protecting 4 earth potential free single line with common reference potential in intrinsically safe measuring circuits. These will be installed within the PLC cabinet on LACT Pump Starter control terminals.*
- *Install a 120VAC and 24VDC power line protectors within the PLC panel on the respective power distribution terminals.*
- *Install a 120VAC Type 1 SPD on the power panel on each of the two 120V supply lines.*
- *Install a 277/480VAC Type 1 SPD on the pump power panel.*
- *There are two Buffer tanks in the truck offloading area with level transmitters. These are at the risk from of induced voltages on the ground reference and induced current on control lines. Install 24VDC SPD ex rated directly to the field instruments for protecting measuring and power supply circuits.*

Soil Resistivity Measurement

Soil resistivity measurement was executed using the 4 point method per IEEE std. 80. The table below represents soil resistivity data expected at the respective soil depth. The data represents that the soil resistance is lowest at the 30Ft level. Using the simplified formula provided by IEEE 142 para 4.1.5 ground rod resistance expected for a 10Ft rod = soil resistivity/ 298. Based on this data the expected resistance of each 10Ft ground rod installed is expected to be 10 Ohm.

Soil Resistivity Measurement	Depth (Ft)	Depth (cm)	Ohm Reading	Soil Resis-tivity (Ohm/cm)
	40	1219.2	0.29	2220.407
	30	914.4	0.24	1378.1837
	20	609.6	0.55	2105.5584
	10	304.8	1.55	2966.9232

Clamp On Meter Reading

Clamp on meter reading was taken on each connection to ground on each of the LACT skid. The value indicate that no circuit was open. It can be concluded that each skid for adequately bonded to the ground rod.

LACT Skid	Ohm Reading 1	Ohm Reading 2
4	**0.286**	**0.255**
5	**0.255**	**0.280**
7	**0.2**	**0.5**
8	**0.18**	**0.5**
9	**0.17**	**0.5**
10	**0.18**	**0.4**
11	**0.17**	**0.4**
12	**0.2**	**0.5**

[redacted]

A typical [redacted] that is located near a production battery. It pumps and measures the pumped fluid to the [redacted]. A number of such pump stations are located at nearby production battery sites. The pump station has a physical dimension of approximately 100 Ft x 100Ft. Based on its vicinity to the production battery, the risk of direct strike to a pump station can be considered high. There is no tall equipment on the station except for light pole. The main equipment's to be protected from any direct strikes would be the following:

- The Power and Control Panel
- Communication Antenna
- Pump
- Manifold and instrumentation
- Buffer Tank

While the direct lightning strikes to the facility itself contribute to the risk of physical equipment damage and fire, the risks of nearby lightning strikes and lightning strikes to power lines are higher. The integrity of electronics onsite is critical to the cost of operation downtime and cost of replacement. These electronics are at risk of physical damage from direct lightning strikes; at risk of failure from induced currents on power and control line and at risk of failure from induced voltages in the grounding system. Each of the Vitol pump stations is recommended to install a custom designed structural lightning protection system, suitable grounding for the structural lightning protection and surge protection devices on power distribution, control and measurement devices on site. Here below are our recommendations for [redacted]

Recommendations:

- *Install two 35Ft lightning air terminals and position them on the opposite end of the manifold to provide an IEC 62305 level 1 lightning zone of protection to the equipment on pump station.*
- *Install UL Type 1/ IEC Class 1 Surge Protection Device on the 277/480VAC Panel to protect the pump motor*
- *Install UL Type 1/ IEC Class 1 Surge protection Device on the 480VAC VFD for the pump to protect the VFD*
- *Install UL Type II/ IEC Class II 120VAC and 24VDC Surge protection devices within the PLC Panel*
- *Install 10 units of 24VDC SPD with Life Check for protecting 1 pair in intrinsically safe measuring circuits. These will be installed within the PLC cabinet.*
- *There is a Buffer tanks in the manifold area with level transmitters. Install 24VDC SPD ex rated directly to the field instruments for protecting measuring and power supply circuits.*
- *Install 24VDC SPD ex rated directly to the four pressure transmitters.*

BILL of MATERIAL for Storage Terminal

	Item Description	Model	Total Quantity	Price	Total Amount
1	480Y/277V AC 3p 4W 3000A Class 1/ Type 1 35kA SPD - remote monitoring and Mount in NEMA enclosure for indoor installation with suitable breaker	908506	25		
2	Power Panel for Control valves 208Y/120V 3P4W Class 1/ Type 1 35kA SPD- remote monitoring and Mount in NEMA enclosure for indoor installation with suitable breaker	908505	1		
3	120VAC SPD Class II/ Type 2 15kA SPD - remote monitoring	952206	13		
	Varistor based protection module for Class II - 120VAC SPD	952012	13		
4	24VDC SPD Class II/ Type 2 10kA up to 60VDC - remote monitoring	952098	15		
	Varistor based protection module for 24VDC SPD	952018	15		
5	24VDC 4-20mA Type 1 24VDC protector with Life Check for 1 pair and Shield with Life Check	920244	96		
	Base for Protection Module	920300	96		
6	24VDC 4-20mA for Field Instrumentation Ex rated 24VDC 3 wire 10kA SPD with 1/4" NPT thread	929963	200		
7	Class 1 SPD for 4 wire RS485 link with Life Check	920370	11		
	Base for Protection Module	920300	11		
8	120VAC SPD Class I/ Type 1 35kA with remote monitoring	961115	20		
	Varistor based protection module for Class I - 120VAC SPD	961001	20		
9	N connector DC to 5.8Ghz Surge protector for Radio Antenna	929045	1		
10	24VDC SPD Ex rated with Life Check for protecting 2 pairs in intrinsically safe measuring circuits	920381	55		
11	24VDC SPD Ex rated with Life Check for protecting 4 earth potential free single line with common reference potential in intrinsically safe measuring circuits	920384	31		
	Base Module	920301	86		
	Total				

Material breakup at Storage Terminal

MSWB 480Y/277VAC	Pump 101 VFD Panel	Pump 102 VFD panel	MOV Panel	Power Panel	LP panel	Power Generator ATS	PLC Control Panel in Control Room	OMNI Panel	CP Panel - External and Internal	Storage Tank	Tank Battery	LACT	Gathering Manifold	Truck off Loading - LACT	Truck off Loading - panels	Model	Total Quantity
1	1	1	1		1	1						2	1	8	8	908506	25
				1												908505	1
							1	1				2	1	8		952206	13
							1	1				2	1	8		952012	13
							1	1	2			2	1	8		952098	15
							1	1	2			2	1	8		952018	15
							32	24				6	10	24		920244	96
							32	24				6	10	24		920300	96
							32	24		42	24	26		108		929963	256
							11									920370	11
							11									920300	11
									2				2	16		961115	20
									2				2	16		961001	20
								1								929045	1
										12	3	8		32		920381	55
										12	9	2		8		920384	31
										24	12	10		40		920301	86

BILL of MATERIAL for Pump Station

		Model	Total Quantity	Price	Total Amount	Peggy Station
1	480Y/277V AC 3p 4W 3000A Class 1/ Type 1 35kA SPD - remote monitoring and Mount in NEMA enclosure for indoor installation with suitable breaker	908506	2			2
2	120VAC SPD Class II/ Type 2 15kA SPD - remote monitoring	952206	1			1
	Varistor based protection module for Class II - 120VAC SPD	952012	1			1
3	24VDC SPD Class II/ Type 2 10kA up to 60VDC - remote monitoring	952098	1			1
	Varistor based protection module for 24VDC SPD	952018	1			1
4	24VDC 4-20mA Type 1 24VDC protector with Life Check for 1 pair and Shield with Life Check	920244	10			10
	Base for Protection Module	920300	10			10
5	24VDC 4-20mA for Field Instrumentation Ex rated 24VDC 3 wire 10kA SPD with 1/4" NPT thread	929963	6			6
6	11mtr Air Terminal System	TBA	2			2
	Total					

Summary of Cost

S.No	Item Description	Total Cost
1	**Estimated material cost for protecting electrical, electronic, control and measurement devices for Main Storage Terminal. Cost does not cover shipping expenses. Installation services are not part of the bill of material.**	
2	**Structural Lightning Protection for Main Storage Terminal**	
3	**Estimated material for structural lightning protection, protecting electrical, electronic, control and measurement devices for a typical Pump Station. Cost does not cover shipping expenses. Installation services are not part of the bill of material.**	
4	**Recommended Maintenance Tools. Life Check SPD Test Device** **Model # 910653**	
5	**Development of corporate standards for design, installation and maintenance of lightning protection system at storage facilities and pump stations.**	

Disclaimer: The above recommendations are in compliance to the international industry standards applicable for lightning protection. Installation of the protection measures items as recommended will provide compliance to standards (NFPA 780 and IEC 62305) and provide best measures to mitigate losses due to lightning events. Installation of the material as recommended does not provide "NO LOSS "guarantee. Petroguardian LLC can provide installation supervision and commissioning services if required but will not provide installation services.

TESTING, MAINTENANCE AND INSPECTION

Inspection

Visual inspections should be performed to verify the following:

- The system is in good repair.
- There are no loose connections that might result in high-resistance connections.
- No part of the system has been weakened by corrosions, vibration, or an obvious lightning strike.
- All down conductors and grounding electrodes are intact (non-severed).
- All conductors and system components are fastened securely to their mounting surfaces and are protected against accidental mechanical displacement.
- There have been no additions or alterations to the protected structure that would require additional protection against lightning strikes or surges.
- There is no indication of damage to surge protection devices.

Frequency of Inspection

- An annual visual inspection should be performed on all visible LPS components per the requirements of IEC 62305
- A visual inspection should be performed after a known or suspected lightning strike or other natural phenomena that could have damaged the LPS.
- The annual visual inspection should be scheduled to proceed the normal lightning high frequency period for the site, if practical.
- A complete inspection of the LPS should be performed on 36 to 60 month frequency as practical for the site.
- This inspection shall include the visual inspection as well as a ground resistance test performed on all, or a specified number, of the ground electrode connections.
- This inspection shall include continuity testing of any components and conductors that are not located so that they can be visually inspected.

Prerequisites

- Obtain the appropriate drawings showing the lightning protection components and installation for use during inspection.
- Obtain safety equipment and tools required to complete the inspection. This should include small wrenches to tighten loose connections, fall protection equipment as required for roof top work, lifts etc.

- Obtain reference materials as necessary.
- Review previous inspection records and any findings and corrective actions as necessary to ensure that deficiencies have been corrected.
- Calibrated test instruments as required for ground resistance and/or continuity testing.
- Individual inspections steps may be performed concurrently.

Annual Inspection Criteria

Visually inspect that the System is in Good Repair;

- *Air terminals are in the vertical position*
- *Verify no broken conductors*
- *Ensure all LPS components are present*

Visually inspect for loose connection or high resistance joints

- *Air terminal Holders*
- *Cable Holders*
- *Tighten loose connection, splices, and bolts as necessary*

Visually inspect to ensure that all down conductors and grounding electrodes are intact

- *Verify down conductors are firmly attached to building walls or steel – 36-in maximum spacing on fasteners*
- *Verify no broken or frayed conductors*
- *If visible inspect ground electrode connections*
- *Tighten loose connection, splices, and bolts as necessary*

Visually inspect all conductors and components to ensure that they are securely fastened to their mounting surface

- *Verify Air terminals are firmly connected their holders*
- *Verify conductors are firmly connected their holders and maintain 36-in maximum spacing*
- *Tighten loose connection, splices, and bolts*

Visually inspect that there are no additions or alterations to the structure that would require additional protection

- *Compare to system drawings and/or component listing*

Visually inspect surge protection devices for indication of damage or overvoltage to devices

- *Inspect for damage to the devices*
- *Verify indicator lights are on and in correct sequence*

Visually inspect and compare to referenced drawings to ensure that the system complies with IEC 62305 requirements

Testing Criteria

Test to verify continuity of those components of the system that are concealed (built in) and are not available for visual inspection

- *Perform continuity testing on all air terminals with respect to ground electrode point.*

Perform a ground resistance test of the grounding electrode system and any individual electrodes that are accessible or visible to test

- *Perform fall of potential ground (three point) test at each test point*
- *Use visible down conductors at building exterior as necessary.*

Perform continuity testing to determine that suitable equipotential bonding has been established for any new services (utility, communication, fire protection, power, CCTV, etc.) or construction that has been added to the structure since the last inspection.

Perform “Life Check” on the control system surge protection devices within the PLC panels.

PERSONNEL SAFETY

Lightning is the second-leading weather killer in the United States. According the National Oceanic & Atmospheric Administrations' (NOAA) National Weather Service (NWS), lightning strikes kill an average of 73 peo- ple and injure another 300 persons each year in the United States.

Most of these tragedies could be avoided with proper planning and simple precautions. Many victims say they were caught outside and could not get to a safe location. Other victims waited too long before seeking shelter. By heading to a safe place about five to ten minutes earlier, they could have avoided being struck by lightning. Some victims say they went back outside too early. Staying inside the safe location just a few more minutes may have saved them from this encounter. Other victims were talking on a corded telephone or using electrical equipment or in contact with plumbing system. Just avoiding physical contact with conductive components could prevent injury from the effects of a lightning strike.

High winds, rainfall, and a darkening cloud cover are the warning signs for possible cloud-to-ground lightning strikes. While many lightning casualties happen at the beginning of an approaching storm, more than 50 percent of lightning deaths occur after the thunderstorm has passed. The lightning threat diminishes after the last sound of thunder, but may persist for more than 30 minutes. When thunderstorms are in the area, but not overhead, the lightning threat still exists when skies are clear.

While nothing offers absolute safety from lightning, some actions can greatly reduce risks to workers. If a storm is approaching, avoid being in, or near, high places, open fields, isolated trees, unprotected gazebos, rain or picnic shelters, communications towers, flagpoles, light poles, metal fences, convertible vehicles, golf carts and water. If you can see lightning or hear thunder, the risk is already present. Louder or more frequent thunder means lightning activity is approaching, increasing the risk for lightning injury or death. If the time delay between seeing the lightning and hearing the thunder is less than 30 seconds, you are in danger.

No place is absolutely safe from a lightning threat, however, some places are safer than others. Large enclosed structures are safer than smaller, or open, structures. When inside during a thunderstorm, avoid using a corded telephone, taking a shower, washing your hands, doing dishes, or having contact with conductive surfaces, including metal doors, window frames, wiring and plumbing. Generally, enclosed metal vehicles, with the windows rolled up, provide good shelter from lightning.

Planning for Personnel Warning

At sites where conditions may exist and subject workers to risk of lightning strikes, an action plan, policy or procedures should be considered to address personal safety during lightning activity. The following elements should be considered in these plans or procedures:

- Monitoring Systems
- When work activities should be suspended and workers notified
- Employee responsibilities and education on lightning safety guidelines
- Safe evacuation locations
- Reassess the hazard and when to resume work
- Emergency procedures and telephone numbers in the event that a person is struck by lightning

General Guidance for Outdoor Workers

Personnel who work outdoors in open spaces, on or near tall objects, with explosives or with conductive materials such as metal, generally have a greater risk to lightning exposure. For example, heavy equipment operators, power utility workers, telecommunication workers and other field labor workers are at greater risk than others. Even though no lightning safety guidelines will ensure 100% safety for a worker, the following steps will help minimize risk of a lightning casualty or strike to an individual.

Know the weather forecast beforehand and discuss in the daily pre-job briefing. Understand and comply with a site warning system if one is used.

Stay attentive to the skies for clues that thunderstorms may be developing, especially for increasing, thickening, and darkening clouds. Seek proper shelter as appropriate. Use the 30-30 rule to know when to seek proper shelter. When you see lightning, count the time until you hear thunder. If time is 30 seconds or less, seek shelter. Wait 30 minutes or more after hearing the last thunder before leaving shelter.

The best shelter is generally a large fully enclosed substantially constructed building that contains electrical wiring and plumbing in the walls. Once inside, stay away from the conducting paths to the outside. Generally, buildings that have exposed openings are not considered safe (picnic shelters, canopies, metal sheds, etc.)

If you can't get to a building, a vehicle with a solid metal or hard topped roof and metal sides is a second choice. Safe vehicles include hard-topped cars, minivans, buses, trucks, etc. Unsafe vehicles include convertibles, golf carts, riding mowers, open cab construction equipment and boats. Avoid contact with any conducting paths going outside and keep the windows closed.

If you can't get to proper shelter or a vehicle, avoid locations that put at an increased risk to lightning strike. The following are examples:

- Higher elevations
- Wide open area such as fields and areas and parking lots
- Tall isolated objects such as trees, towers, and poles
- Water
- Near or in contact with metal fences or other metal structures that can conduct electricity, including metal scaffolding and equipment
- Large equipment such as bulldozers, cranes, backhoes, track loaders and tractors
- Tops of buildings

If caught in an exposed area with no shelter available, seek depressed areas or dense woods (but not isolated trees). Crouch as low as possible and kneel on ground while maintaining feet together. Keep as low as possible but do no place hands on ground so that risk of step potential hazard is minimized. If near a tree or other high structure, move away while shuffling feet keeping constant contact with the ground.