1. Harbor Electrical Maintenance and Operations

1.1. Basic System Description

The harbor electrical system obtains the power from the utility primary. The harbor transformer is furnished with the harbor facilities or by the utility and reduces the voltage from 2.4, 4.16 or 12.47 kilovolts to 120/240 volts, single phase, 120/208 volts or 480 volts, 3 phase. The harbor main service disconnect and master meter are usually located adjacent to the transformer. The secondary service from the transformer to the harbor is normally installed below the dock and down the gangway to a distribution panel. The latter subdivides the circuits with one circuit to each side of each major float. Some harbors have a submarine cable for service. The distribution in the float system is a type "W" double jacketed neoprene composite cable impervious to oil, gasoline, etc., and suitable for immersion in salt water. On wood floats, the cable is attached to the stringer and is visible below the decking. On older concrete floats, the cable is in a notch between the wale and the concrete. In newer concrete float systems, the cable is either in a duct or trench.

The lighting system is normally overhead supported on the piling with a separate shore panel and control. Some of the three phase lighting systems can be operated at 1/3, 2/3 or all on as a possible energy savings or harbor utilization.

The power to the grid is generally derived from a separate ground fault breaker on the line side of the connector in the lighting panel. On a 480 volt system, the grid power is derived from a separate transformer with a ground fault circuit breaker on the secondary side. If a faulty piece of equipment is connected to the system, the circuit breaker will trip and disconnect the circuit with ground current flows exceeding 5 milliamperes (.005 amperes).

There are several harbors that have a combined overhead lighting and power distribution system. These systems have been installed with aluminum wire which is subject to corrosion and have a bare messenger ground contrary to the Code requirements for an insulated ground. The systems also generally lack circuit breaker or fuse protection for the feeders and the ability to isolate problems by systematically opening circuits.

Note: Some harbors with older systems employ aluminum wire which is subject to corrosion and lack fuses or circuit breakers. These should be scheduled for changeover.

1.2. System Operation

Generally, the electrical power flows from the utility primary through the transformer, master meter, disconnect, service, main distribution panel, individual float feeder, individual meter and shore power receptacle to the individual vessel.

In a 2-wire, 120 volt system, the energy flows through the hot lead and returns via the neutral. In a 120/240 volt single phase system, the energy flows through the two hot leads. Since the energy is alternating between the two hot leads, the neutral or white conductor carries only the unbalance of the system. In a three phase system, there are four conductors, but again the neutral or white wire carries only the unbalance of the system. The insulated ground wire of the system does not normally carry any energy but bonds the system and all the vessels together at the zero potential of salt water.

1.3. Trouble Shooting

When attempting to isolate some type of problem, any portion of the system may be isolated by opening each feeder circuit breaker, where installed, to determine which float and side is involved. Subsequently the individual circuit breaker or the shore plug may be opened to determine the vessel which is causing the fault. A common problem is a vessel's cord being connected to receive power between the hot and ground rather than the hot and neutral. This can be detected with an amprobe to measure current flow utilizing an adapter assembly as shown in Appendix A.

Note: *If more than one vessel is causing a fault, it may be necessary to disconnect all vessels and reconnect them individually in order to discover the vessels which are causing problems.*

The float feeder cable size is selected on the basis of 2%-5% voltage drop when fully loaded, normally in cold winter months. If the voltage at the panel is a nominal 120 volts and voltages below 115 volts are reported, look for loose terminals in a meter cabinet.

If a feeder circuit breaker trips the circuit breaker may be faulty, an unbalance may exist in the feeder, or an overload may exist. The services of an electrician will be necessary to evaluate the condition or change the circuit breaker.

1.4. Power Consumption

The majority of the harbors have a master meter to register kilowatt hours as energy and kilowatt demand. The latter records the maximum load in any 15 minute period until reset, usually each month. The maximum load should be compared to the previous years recordings to determine the growth rate in electrical demand and to predict the total power demand.

Each shore power outlet has an individual meter, and any substantial deviation from the previous month's reading may be electrolysis or may be caused by some other reason such as a refrigerator or space heater running continually.

1.5. Maintenance

When properly installed, the electrical system in a boat harbor facility should last over 20 years with reasonable care. Any deficiencies which occur should be promptly repaired, and deferring minor repairs may result in subsequent major repairs.

Heat is a good indication of a problem. Any circuit breaker frame, either in the panel or shore panel outlet, which feels warm may have loose connections or corrosion which increases the resistance and, in turn, results in heat. The type W cable should be checked periodically for rubbing or abrasion at the float hinge points, particularly if any swell is present. Some of the older harbors which have meter stands and cast boxes for the outlets and circuit breakers use Crouse-Hinds cast aluminum covers for the circuit breakers which were subject to corrosion. A light penetrating oil at the operating shaft would free the mechanism. In some harbors, the receptacle bodies are black porcelain which has a tendency to crack with abuse. If cracked, the receptacles should be replaced with nylon or melamine receptacles.

Note: Panels or circuit breaker frames which are warm to the touch should be checked for loose connections or corrosion.

If any components are made of steel, either galvanealed or galvanized, any rust spots should be sanded and cleaned and cold galvanizing sprayed on the surface. Galvanealing is a hot dip process on the initial sheet metal prior to fabrication, but galvanizing is a hot dip process after fabrication. Galvanealing is subject to rusting where the initial sheet is cut.

With the exception of light fixtures in areas of high winds near salt water, chemical corrosion has not been a serious problem in properly wired marine facilities. Where chemical corrosion occurs in panels, meter cabinets, etc., it will appear as a blotchy area generally white in appearance. If it does occur, the circuit should be de-energized and tagged prior to cleaning the area or terminal with a brass wire brush and applying a nonconductive, nonflammable corrosion inhibitor spray such as CRC or Hoffman A-HC123GS. If an electrical connection problem develops, particularly between copper wire and aluminum bus bars, an oxide inhibitor/sealer such as Ilsco DE-OX-A-35 or Burndy Penetrox A can be applied. The material will penetrate the oxide film, reduce the contact resistance and seal the joint from air and moisture.

The overhead lighting wiring should be checked each fall for excessive sag, rubbing on adjacent piling or broken insulators or the copperclad messenger not being fastened to the insulators and then repaired as required. The minimum clearance to the float at extreme high tide is ten (10) feet.

Also trollers with forward slanting bow poles or sail boats with spreader bars should not be moored where there is any possibility of interference with the overhead lighting circuits.

Note: Ensure that vessels are moored so as to avoid contact with overhead lighting conductors.

1.6. Galvanic Corrosion/Electrolysis

Galvanic corrosion is caused by a natural battery formed by two dissimilar metals connected together and immersed in an electrolyte such as salt water. For example, non-marine grade brass bolts or screws are an alloy of copper and zinc and can develop galvanic corrosion when immersed or subject to salt water and the zinc portion will deteriorate. A table of the galvanic series of metals is included in Appendix B. Included in Appendix C is a tabulation of corrosion potentials. As an example, the difference between zinc and bronze is 0.6 volts which is small but destructive over a long period of time.

Some possible sources of galvanic corrosion are:

a. Different types of metal immersed in salt water or moisture that are touching each other or connected with a conductor. See Appendixes B & C.
b. Vessels of incompatible hull construction such as aluminum and steel. Aluminum vessels should not be moored adjacent to steel vessels.
c. Bottom paint with different compositions, such as arsenic, copper or tin.

Note: Vessels with dissimilar metal hulls, types of battery grounds or bottom paint compositions should be segregated, if possible, to minimize galvanic or stray current corrosion.

Stray current corrosion or electrolysis is the result of a direct current potential difference between two items which could be within a vessel or from some other vessel. Stray current corrosion is much more destructive than galvanic corrosion due to the possibility of increased voltages involved.

Some possible sources of stray current corrosion are:

a. A direct current welder which uses the salt water as a partial return path as the result of poor or frayed cables. The ideal solution is to place the welder on the vessel.
b. An engine with a positive ground moored next to a vessel with a negative ground.
c. Two bilge pumps which have the connections reversed. (The frame of one pump is connected to the negative, and the frame of the other pump is connected to the positive.)
d. A common automotive battery charger which has an auto transformer (the primary and secondary windings are electrically connected). The primary and secondary windings should be completely separate and isolated. Only isolation transformer battery chargers should be allowed in the harbor.

   Note: Ensure that battery chargers used in the harbor are isolated between the primary and secondary windings.
e. A reverse polarity indicator on a boat with a resistance of less than 100,000 ohms at 120 volts, 60 Hz.
f. The ground and neutral of the vessel not completely isolated. This can be checked with a regular ohm meter at the ship's cord plug. The ohm meter should read infinite resistance to show complete isolation.
g. The vessel cord not properly connected to the hot, neutral and ground shore power outlet. Any vessel which is connected to receive power between the hot and ground in lieu of the hot and neutral should be disconnected. Power derived at the ground will result in a voltage drop in the ground system and, in turn, create another path for stray current corrosion between two vessels. Any new vessel in a harbor should be checked to insure that the ship's ground and neutral are isolated and the power is only taken between the hot and neutral terminals. As shown in Appendix A, a socket and plug with approximately 8" of color coded wire can be inserted between the shore outlet and ship's plug. A clamp-on ammeter can be used to measure the current flow in each conductor. The current flow in the green (ground) wire should be zero.

   Note: New vessels in the harbor should be checked to insure that the ship's ground and neutral are isolated and the power is only taken between the hot and neutral terminals. A similar survey of all the existing vessels is also recommended.

h. Leakage from the telephone system. A telephone has a positive 48 volts ground, and a fault within the telephone instrument in combination with salt water could impress a portion of the positive D.C. voltage across the vessel. Any severe corrosion near a telephone outlet should be checked thoroughly.
i. The ground conductor within the harbor not completely isolated from the neutral except at the main service. The current will flow in the ground conductor creating a difference in voltage between portions of the system and, in turn, between vessels.

At some harbors, primarily in western Alaska, the utilities require a wye-wye primary-secondary transformer or interconnect the primary and secondary neutrals which can result in current flow from the utility through the ground system to salt water. The preferred system is a delta-wye connection which effectively isolates the utility system from the harbor electrical system.

An ideal solution to all stray current corrosion or electrolysis is an isolation transformer for each vessel. However, the cost is prohibitive.

Individual isolated galvanized steel piling will not be affected by electrolysis but may be subject to galvanic corrosion, particularly where different metals such as welds or bolts are involved. Dock structure galvanized piling where electric systems are involved will be more subject to stray current corrosion as noted above.

The majority of all known problems of stray current corrosion are derived from vessels in the harbor rather than the shore power system. Any evidence of rapid deterioration of vessel zincs or pitting of exterior fittings should be checked and the trouble isolated and corrected.

Note: Most harbor electrical problems are due to the vessels rather than the harbor system.

1.7. Vessel/Shore Power Connection

In the majority of the harbors, the standard outlet is a NEMA L5-30, 30 ampere, 125 volt locking receptacle protected with a 20 ampere circuit breaker. The plug has 3 prongs with the ground prong being longer and having a turned edge. The longer ground terminal that the ground is connected prior to the hot or neutral connection. The neutral (white) and the hot (black) terminals are positioned in a counterclockwise direction from the ground (green). A 20 ampere, 125 volt plug or a 125/250 volt plug cannot be inserted in a 30 ampere, 125 volt receptacle.

Where a new vessel is proposed to connect to the shore power, the neutral and ground leads of the ship plug should be measured with an ohm meter which should read infinity indicating isolation. A similar survey of all the existing vessels is also recommended. A test plug/receptacle as shown in Appendix A should be inserted between the shore power and vessel cord. A clamp-on ammeter should be attached to the green wire which should read zero amperes. The cord between the ship and shore power outlet should be not less than 3/conductor (ground, neutral and hot) #12 (rated at 20 amperes) to insure the ship is properly grounded. Ordinary extension cords; should not be permitted since the carrying capacity is below the 20 ampere circuit breakers and normally are only 2 conductor or missing the separate ground conductor.

Note: Ordinary extension cords should not be permitted between the vessel and harbor power outlet unless they are adequate in current carrying capacity and include an insulated ground conductor.

1.8. Ground Fault Interrupter (GFI) Systems

A ground fault circuit interrupter is not provided for each outlet. Ground fault circuit interrupters such as the ones used in residential bathrooms, exterior outlets and swimming pools are set to trip on 5 milliamperes (.005 amperes). There is sufficient leakage around the salt water environment of a boat harbor to continually trip the circuit breaker and be of more nuisance than value.

A number of harbors are equipped with ground fault relays in the main or subpanels which will show a green light for no fault and red for ground faults drawing more than 5 amperes. When the red light is on, some vessel is drawing power more than 5 amperes through the ground conductor rather than the neutral as the result of improper connections. By turning off the float circuit breakers one at a time to determine the float involved and then turning off the individual shore power outlets until the vessel involved is isolated, the red light will change to green. The vessel should not be allowed to reconnect until the proper connections are made. If the red light is allowed to remain on and more than one vessel is involved, a test of each outlet with the adapter will be required to determine which vessels are involved.

Note: When a red light is displayed on a main or subpanel with a ground fault relay, the source of the ground fault should be located and corrected.

1.9. Materials

The materials used in a harbor electrical system should be high quality corrosion resistant marine grade. All of the electrical components should be copper. All of the exposed screws and small bolts should be stainless steel or marine grade bronze, and the larger bolts and lag screws should be hot-dip galvanized. Aluminum is used for some meter stands but is limited to marine grade 5052 or 5086. Some harbors have #316 stainless steel meter stands.

There are a number of manufacturers involved in furnishing materials for boat harbor electrical systems. However, the majority are wholesale and furnish the materials through the following distributors:

North Coast Electric Co.
P. O. Box 80566
2424 8th Avenue South
Seattle, Washington 98124
Telephone:
(206) 682-4444

Debenham Electric Supply Co.
5333 Fairbanks St.
Anchorage, Alaska 99518
Telephone:
(907)-562-2800

Stusser Electric Co.
660 South Andover Street
Seattle, Washington 98108
Telephone:
(206) 623-1501

Delta Alaska Wholesale
2425 Industrial Blvd.
Juneau, Alaska 99801
Telephone:
(907)-789-2880

1.10. Lighting Upgrade

The majority of the older boat harbors have mercury vapor lights which can be replaced with high pressure sodium lights with a relatively short payback.

Type	Wattage	Lumens	Life	KWHR/YR
Mercury Vapor	175	8600	24,000 hrs.	701
High Pressure Sodium	100	9500	24,000 hrs.	438

Based upon 11 hours of operation per day (year round average), the following cost difference is calculated for the two types of lights, for 5 different electrical rates. Further, the bottom row shows the lifetime savings assuming 6 years of lamp life. If this figure is more than the difference in cost for the two lights, it would be beneficial to make the changeover.

Savings at varying electrical rates:

Cost/KwH	8¢	12¢	16¢	24¢	36¢
Cost per fixture- MV	$56	$84	$112	$168	$253
Cost per fixture-HPS	$32	$48	$64	$96	$145
Savings-6 yr. typ. life	$144	$216	$288	$432	$648

1.11. Modifying/Maintaining the Electrical System

The harbor electrical system is only as good as the individual components. All the wire, bus bars etc., should be of copper. The mixing of copper and aluminum parts will lead to corrosion and electrolysis. If any type W cable requires replacing, be sure to specify and obtain only the premium grade such as Royal Powerflex 90. Due to the cost involved, several companies manufacture cheaper grades which will not be suitable for salt water. Also insist on a certificate attesting to the date of manufacture to insure that the cable is not surplus or has been stored in some warehouse for years. In one harbor, all the cable had to be replaced after three months of service as the result of old cable which had been in a warehouse for years and found to have SBR (styrene butadiene rubber) insulation rather than EPR (ethylene propylene rubber) insulation specified. Any replacement of the type W cable requires replacing the entire cable. No splices are to be introduced in the electrical system. If technical assistance is required, contact personnel familiar with the problem.

Note: Copper and aluminum conductors should not be mixed due to corrosion potential.

1.12. References

Unfortunately, written material on marina or boat harbor electrical problems is scarce. One reference which is recommended and would be of value is "Your Boat's Electrical System" written by Conrad Miller and E. S. Maloney. While the majority of the book is for the boat owner, there is a chapter on corrosion and electrolysis and some data on shore power and the proper connections. The book is written by engineers but the data is written in nontechnical language and easy to understand.

1.13. Accessories

Recommended test instruments for maintenance of boat harbor electrical systems are as follows:

Amprobe or clamp-on volt-ohm ammeter (Approximately $175.00)

j. TIF Instruments, Inc. Model 1000
9101 N. W. 7th Avenue
Miami, Florida 33150

k. Amprobe Instruments Model ACD-2
Lynbrook, New York 11563

l. Fluke Corp Model 33
P.O Box 9090
Everett, Washington 98206
(206-347-6100)

Digital Multimeter (Approximately $200.00)

m. Beckman Instruments, Inc.
Model Tech 310
2500 Harbor Boulevard
Fullerton, California 92634

n. Amprobe Instruments
Model AM-4
Lynbrook, New York 11563

o. Fluke Corp Model 73
P.O. Box 9090
Everett, Washington 98206
Telephone (206)-347-6100)