2. Harbor Electrical Design

2.1. Codes

The codes which influence the electrical design of a marina are:

p. National Fire Protection Association, NFPA 303, (Marinas and Boatyards),
q. National Fire Protection Association, NFPA 70 (National Electrical Code or NEC), and
r. National Electrical Safety Code (NESC), ANSI C2.

Article 555 of the National Electrical Code was first included in the 1968 NEC and was derived from NFPA 303. The latter was first adopted in 1940 and completely revised in 1963 and 1986. The majority of the pertinent requirements of NFPA 303 have been transferred to Article 555 of the NEC over the past 25 years.

Some of the major provisions of NFPA 303 are:

- 3-2 All wiring, conduit enclosures and equipment to conform to the NEC.
- 3-4 All areas above the pier deck or above the datum plane (2'-0" above the highest tide) to be classified as "Damp."
- 3-4 All areas below the datum plane to be classified as "Wet."
- 3-5.6 The service equipment to be located in a damp location and protected from the weather.
- 3-6 All noncurrent carrying parts of the system to be bonded and grounded with separately insulated ground wires.
- 3-12 All wiring to be in rigid metal conduit or rigid nonmetallic conduit except where flexibility is required. Type W conductor fastened with nonmetallic clips is permitted in lieu of conduit.
- 3-12.1 Circuit breakers to be required rather than fuses.
- 3-15.2 Receptacles to be not less than 20 amperes and of a locking and grounding type conforming to ANSI C73.

Some of the applicable provisions of NEC 70 are:

- 555-3 Shore power receptacles to be of the locking and grounding type and not less than 30 amperes except that 20 amperes may be used for boats less than 20'. Receptacles other than for shore power to be protected with ground fault circuit interrupters (GFI).
- 555-5 The electrical loads for the feeders and service to be calculated on a varying schedule from 100% to 20% of the sum of the ratings of the receptacles.
- 555-6 The wiring method to be of a type for wet locations.
- 555-7 The ground conductors to be insulated copper and terminate at the main service equipment.

The main applicable provisions of the NESC is the minimum overhead clearance of wires for lighting circuits. Table 232-2 provides for a minimum of 13' for "spaces and ways accessible to pedestrians only." Note "B" further reduces the clearance to 10' if the voltage to ground is less than 150 volts. Other provisions of this Code would apply to any pole line or underground service.

2.2. Load Factors

Section 555-2b of the 1968 NEC included a requirement for load factors for feeders and services to be calculated on the basis of 25 watts per lineal foot of slip or dock space for boat outlet circuits plus lighting and other electrical loads. The same requirement was included in the 1971 NEC as 555-5. The 25 watts per lineal foot was dropped in the 1975 Code in favor of:

1 - 4 Receptacles	100%
5 - 8 Receptacles	90%
9 - 13 Receptacles	80%
14 and over Receptacles	70%

The 1975 preprint of the NEC states the reason for the change is "the present wording and requirements are ambiguous, unrealistic and difficult to enforce."

The preprint of the proposed amendments for the 1978 NEC proposed to change the demand factor of NEC 555-5 and included the following summary of 3 California marinas.

	#1	#2	#3
Actual Maximum Demand KW	39.6	21.8	45.6
Design Based on 25 w/ft	86.6	45.4	126.25
Design Based on 1975 Code	186.2	92.4	396.0

The 1975 NEC changed the 100 and over outlets range to 30% demand which was changed again in the 1987 NEC to 20% demand.

Although the 25 watts per lineal foot of stall method is preferred for design purposes neither method will produce accurate results due to a number of variables involved such as:

s. The Cost of Electricity. The rate for electricity varies from 5.5 cents/KWHR to 38 cents/KWHR plus a fixed customer charge, if any, has a major impact on the harbor electrical demand. As an example, the Hoonah boat harbor constructed in 1981 has 6004 LF of stall but a density of 1.19 watts/ft summer and 4.0 watts/ft winter as the result of an electricity cost of 38 cents/KWHR.

t. The Type and Size of Vessel. A commercial vessel will generally require less demand than a pleasure boat as the result of the use of oil stoves and the more frequent absences from the harbor. The Haines harbor has a high percentage of transient gillnet vessels which results in a relatively high summer and low winter electrical load.

u. The Location of the Harbor. A remote harbor which is not adjacent to the harbor users may have a high demand load. As an example, the Whittier harbor primarily has pleasure boats for Anchorage residents together with a relatively low electrical rate resulting in the highest demand load of any harbor. The maximum load of 24.2 watts/lineal foot of stall was recorded in March 1979. Also, the actual load factor (total kilowatt hours consumption divided by the demand KW x 24 hours x period) is approximately 80%. The minimum summer load was 4.95 watts per lineal foot.

While the 25 watts/lineal foot of stall with some load factor is recommended for design, the parameters and composition of each harbor should be carefully considered before selecting the anticipated demand or load. The design should also provide for the demand if the rate of electricity decreases.

To facilitate future designs, the data and graphs of three existing harbor electrical load data is included as Appendixes D, E and F. The three harbors selected have low, average and high electrical loads. All harbors have 30 ampere, 120 volt (L5-30R) receptacles and are protected with 20 ampere single pole circuit breakers. The information given is an average for the harbor segment. The watts per lineal foot of stall will be fairly uniform across the harbor, however, the watts per outlet will vary with the stall length. Smaller boats will require less electrical energy and the number of vessels physically connected to shore power will decrease.

1. **Hoonah Boat Harbor** has 4 floats with stalls from 24 to 62 lineal feet. The electric rate is $0.38 per kilowatt hour which substantially affects the electric load. The maximum load in 1996 was 4.2 watts per lineal foot of stall and 157.7 watts per outlet. The minimum load was 1.5 watts per lineal foot of stall and 57.7 watts per outlet. The July electrical maximum almost equaled the winter maximum as the result of stateside pleasure boats visiting Hoonah enroute to Glacier Bay.

2. **Ketchikan Bar Harbor North** has 8 float systems with varying stall lengths from 24 to 62 lineal feet. The maximum load in 1996 was 9.6 watts per lineal foot of stall and 643.4 watts per outlet. The minimum load during the same period was 1.9 watts per lineal foot of stall and 124 watts per outlet. The load factor varies from 72.1% to 43.6%.

3. **Whittier Boat Harbor** (floats D, E, F &G)

has 4 floats with stalls from 24 to 32 lineal feet. The maximum electrical load in 1991 for these floats was 16.1 watts per lineal foot of stall and 865.8 watts per outlet. The minimum in 1991 was 8.3 watts per foot and 444.7 watts per outlet. The load factor varies from 80.1% in the winter to 69.0% in the summer. The electrical load in 1996 showed a drop of 22% from 1991. This drop could be related to the increase in electrical rate or temperature change. The meter for floats A, B & C includes the harbormaster's office, restaurant, fuel dock and exterior lights and does not reflect a true value for the electrical load so these are not included in this report.

2.3. Primary System

The majority of the utility primary systems are 2400 volts, 3 phase delta, 2400/4160, 3 phase wye or 7200/12,470, 3 phase wye. Most of the utilities where available and particularly those involved with REA standards prefer and insist on wye-wye transformer connections. The purpose is to avoid or decrease any possibility of ferroresonance and destruction of the transformer. This can occur with single phase switching of a 3 phase transformer with an underground primary feeder if the inductive and capacitive reactance are equal.

The preferred connection in any boat harbor with 3-phase distribution is delta-wye to insure that any ground current in the utility neutral will not flow to salt water through the neutral and ground conductors and create a difference in potential between different parts of the harbor. One solution for averting ferroresonance with a delta-wye connection is to provide a 3-phase oil switch within the transformer to be used to energize the 3-phase circuit conductors simultaneously rather than a single phase operation at the pole.

If the boat harbor transformer is single phase, again the primary and secondary should be isolated. If no other solution exists, an isolation transformer is recommended.

2.4. Secondary System

There are a variety of systems available which require correlation with the size and layout of the harbor:

v. 120/240 volts, single phase;
w. 120/208 volts, three phase wye;
x. 480 volts, single phase with subsequent reduction to 120/240 volts;
y. 480 volts, three phase delta with subsequent reduction to 120/240 volts, single phase;
z. 480 volts, three phase delta with subsequent reduction to 120/208 volts, three phase.

If the float system contains a main float plus three or more finger floats, the system described in item "d" is preferred. Other advantages of "d" are the isolation of the ground system, reduction of the voltage drop and the use of standard meters. Items "b" and "e" require more expensive network meters. Items "c," "d" and "e" require marine transformers on the main float at the intersections of the fingers. Since the transformers are large and weigh approximately 600 pounds each, additional floatation and float width may be required.

The 120/240 volts, single phase shown in item "a" is generally used for small boat harbors. Item "b," 120/208 volts, 3 phase, 4 wire, is preferred for low voltage when available since a 25% increase in conductors will result in a capacity increase of 50%. The one disadvantage, however, is the requirement for network meters when connected across 208 volts.

The secondary service 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 do have a submarine cable for service.

2.5. Harbor Layout

The harbor layout has an impact on the electrical design. The electrical engineer should be involved at the initial phase to coordinate the gangway locations and the type of float system proposed. Electrically, the dock and gangway should be at the center of small harbors and at the 1/3 points for larger harbors. A dock and gangway at the ends of a harbor layout creates a problem of voltage drop, increased cable size and cost. If the dock and gangway cannot be located except at the end, a 480 volt system with transformers along the main float is recommended.

The piling layout will have an effect on the overhead lighting cables. A piling at each intersection is required to insure that the lighting cables will be above the floats rather than the waterway where they could be interfere with vessels.

2.6. Float System Types

There are several varieties of float systems.

aa. Treated timber floats with foam flotation. The float system may or may not have bull rails.
bb. Concrete floats with a notch recessed approximately 3"x 3" between the wale and concrete. This type of float was discontinued in 1980 in favor of "c."
cc. Concrete floats without the notch but with either a trench or duct system or a combination of both.

From the electrical design viewpoint, the preferred float system is item "a," timber floats, which has the maximum flexibility for the initial and future requirements. Item "c" is the least desirable, especially the duct system, because of the restricted space for any future expansion. The effect of sun on the trench covers will increase the trench temperature and shorten the cable life.

2.7. Conduit And Ducts

All conduit for underground upland electrical wiring should be rigid galvanized conduit with two coats of bitumastic paint. Rigid schedule 40 nonmetallic conduit or duct may be used either exposed or underground subject to the limitations of the NEC. All conduit should be assembled watertight. Rigid aluminum conduit is not recommended adjacent to salt water.

2.8. Wiring

All wiring should be stranded copper, 600 volts minimum. All upland wiring should be type THW, THWN or XHHW in conduit. Aluminum wiring is not recommended for marine wiring due to corrosion. All wiring down the gangway and throughout the float system should be type W copper stranded with type EPR (ethylene-propylene-rubber), or equal, insulation. The conductors should have a minimum of 259 strands. The insulation of type W cable using SBR (styrene butadiene rubber) compound is subject to cracking and should not be used. The outer jacket should be double jacketed neoprene, cured in lead and identified by size, number of conductors, voltage, temperature and a number such as P122MESA. The 122 is a designation for "Royal" and the P-MESA indicates approval of the Pennsylvania Department of Mines and the U. S. Mining Enforcement and Safety Administration. A UL label can also be applied if requested on type W cables.

There is also a type G cable which has been used in some marinas in the contiguous 48 states. Type G cable is similar to type W except the ground wires such as 3- #8 for #2 cable are not normally insulated and do not meet the requirements of an insulated ground in NEC 555-7b.

Some of the MESA numbers assigned to various manufacturers are:

P104	The Okonite Company
P105	Rome Cable Corporation
P108	General Electric (discontinued production)
P120	Hatfield Wire and Cable
P122	ITT (Royal Electric)
P123	Carol Cable Company
P125	Anaconda-Ericsson Inc.

Several firms manufacture type W cable in more than one grade. ITT (Royal) manufactures "Power Flex 90" as their premium grade besides manufacturing an industrial grade. Normally, the premium grades have a double neoprene or hypalon jacket whereas the lesser grades have only a single jacket.

Specifications for type W cable should specify the premium grade and require a certificate indicating the various tests conducted and the date of manufacture. This will insure that the cable is new and has not been stored in some warehouse for a number of years.

Type W cable has the capacity for continuous operation at 90° C or 194°F and 40˚C or 104˚F ambient. Since the maximum electrical load on the harbor will occur during the winter months, the operating current of the cable can be increased 15-20 per cent providing the overall system voltage drop is less than five per cent. The main feeder or the service from the main disconnect (usually located adjacent to utility transformer) to the float distribution panel is normally one or two runs of 4/O type W cable which can be increased in ampacity. The float feeders should be on each side of each float and are normally 4 conductors (2 hots, neutral and ground). The maximum feeder voltage drop should be 2.5 percent at 100 per cent power factor at maximum load. A long float will require two runs for each side.

The bending radius of type W cable is normally eight times the diameter.

All cable terminations on the float system must be in the pedestals. No splices or junction boxes are allowed in the float system. Clamps used to support type W cable need to be either wood or PVC coated to protect from wear.

Wiring for the overhead lighting should be stranded copper, 3/c for single phase or 4/c for three phase plus 30 per cent copper messenger and a PVC coated copper strap. The wiring assembly should be GE #SI58069, PIRELLI or Service Wire Co. cable.

2.9. Lighting

The lighting in practically all the marinas has been overhead. Many of the recently used fixtures have been Holophane 216C-120 v 100 W HPS installed on the pilings as shown in Exhibit A, sheet E-3. This fixture is no longer manufactured. A possible replacement is a Halophane Petrolux II Marine fixture, UL 595. The fixture should be suitable for a marine environment. One-hundred watt HPS fixtures installed on pilings with 75' spacing will provide the recommended foot-candle level of 0.3 with a uniformity ratio of 1-1.5 at mid-tide. Upland fixtures which are normally higher in elevation should be marine grade with a cutoff to preclude any light hindering navigation or impacting upland owners. The lighting is generally controlled by a contactor with a photoelectric cell. Where three phase power is used, each phase should control every third fixture through individual circuit breakers. Where the cost of electricity is high, a portion of the lights can be turned off as a cost saving if warranted. The electricity used as lighting can be metered separately and allocated accordingly.

A pole is required at the end of the approach dock for the transition of conduit to overhead as shown in Exhibit A, sheet E-4. The span to the float piling should be minimum to avoid side thrust of the float piling.

The minimum overhead clearance of the cable midspan should be not less than 10'-0" at 90° F above the float deck per the National Electrical Safety Code if 120 v. fixtures are used. A clearance of 12' is recommended for additional clearance and to leave room for a telephone circuit at 10', if required. The sag may be as noted on Exhibit A, sheet E-3. While the pole extension will provide clearance for the cables at the intermediate piling, an additional support as shown on Exhibit A, sheet E-3 is recommended.

Where the harbor configuration is such that boats tie parallel to the main float, overhead circuits should be placed as far from the parallel moorage as possible to eliminate potential contact with rigging, antennas, etc. This is depicted in Exhibit A, sheet E-l.

The disadvantage of overhead lighting circuits is the possibility of trolling boats with bow poles slanting forward or large vessels with anchors or similar gear contacting the overhead circuits particularly at high tide. Reversing the mooring of these vessels usually alleviates the problem.

Light fixtures and poles mounted on the floats have been used on several installations. However, the illumination level is quite low and the poles are susceptible to damage by vessels.

2.10. Meter Stands

Prior to 1976, all the meter stands specified in the various harbor electrical projects were angle iron galvanized frames with separate components as shown on Exhibit A, sheet E-5. This 1982 project used the original angle iron frames assembled to match a previous project at Ketchikan Bar Harbor. After 1977, meter stands from various manufacturers (primarily Midwest, Unicorn and Daniel Woodhead) have been used. The latter utilized a fiberglass enclosure which was not susceptible to rust. The standard production models of the other two manufacturers used galvanealed sheet metal for the enclosure. In this process, the initial metal sheets are hot dipped, galvanized and rolled. The rolling process produces a flat smooth surface for the bonding of the paint. The problem with the galvanealed process is that during the fabrication process, the sheet metal is cut and the only protection from rusting at the cut is the finish paint. The base plate attached to the deck is particularly susceptible to rust. Meter stands constructed of #316 stainless steel or type 5052 or 5086 marine grade aluminum stands have been specified. In some installations, a flared skirt is required to accommodate the cable train either along the float or perpendicular to the bull rail. A flared skirt is not required if a trench is used which is of sufficient depth to accommodate the cable train as shown in Exhibit B, sheet E-5. Meter stands should be attached to the bull rail to avoid the use of inserts on concrete decks. Receptacles in the meter stands should be in the bottom to protect the receptacle from the elements.

Harbormasters have expressed a desire to utilize the galvanized angle iron frame meter stand (see Exhibit A, sheet E-5) because of the ease with component replacement and less initial cost. The designer should receive guidance from the facility owner as to the type to be installed.

2.11. Receptacles

Receptacle outlets should be standardized to allow interchangeability within Alaska. The recommended receptacles and circuit protection is as follows:

dd. 120 volt, single phase, 30 ampere receptacle NEMA L5-30R protected by a 20 ampere circuit breaker.

ee. 120 volt single phase 50 ampere receptacle (no NEMA standard) Hubbell #63CM70 or Marinco 6370CR with 50 ampere single pole circuit breaker.

ff. 120/240 volt single phase 30 ampere receptacle NEMA L14-30R protected by either a 20 or 30 ampere 2-pole circuit breaker.

gg. 120-240 volt single phase 50 ampere receptacle (no NEMA standard) Hubbell #63CM69 or Marinco 6369CR (isolated neutral and ground) with 50 ampere 2-pole circuit breaker.

hh. 120/208 volt three phase (no NEMA standard) Crouse-Hinds #AR1041 or to match ship (isolated neutral and ground).

2.12. Tides

The tides in southeastern Alaska range from 15 feet near the ocean to 26 feet in Juneau and slightly less in Ketchikan, Wrangell and Petersburg. The Homer-Seldovia area has a tide range of over 27 feet, and the Aleutian Island areas less than 6 feet.

The electrical power from the dock or shore to the float system is normally routed down the gangway, and the cabling will be required to accommodate the tidal range. The amount of gangway travel is related to the extreme low to extreme high tide and the gangway length. At the dock, the gangway will swing approximately 30˚ from the horizontal for a 50' gangway and 20° for a 75' gangway. A junction box is required at the dock end for terminating the wire and conduit and as a transition to the flexible type W cable. A loop or slack span with grips will accommodate the gangway hinge action.

A support column is required at the gangway float as shown in Exhibit B, sheet E-4. The slack in the cable at the foot of the gangway should be calculated so that at high tide the cable does not droop into the water and at low tide the cable is long enough to prevent strain on the cable. The midpoint between the point on the gangway and the point on the post should be the area where the vertical and horizontal travel of the gangway is equal from extreme high water to extreme low water. This point can be calculated or plotted graphically. The portion of the cable along the gangway can be protected with conduit, but this is usually not necessary. Stainless steel grips and a spring should be used as shown on Exhibit A, sheet E-4 to support the cable.

2.13. Materials

All materials exposed to salt water should be marine grade. Sheet metal should be type 316 stainless steel. Marine grade aluminum #5052 or #5086 are optional materials. Bus bars, if used in meter stand panels and transformers, should be copper rather than aluminum. All bolts, nuts, washers and rivets 1/4" and smaller should be either stainless steel or marine grade brass. Exterior bolts, lags and washers larger than 1/4" should be hot dipped galvanized. The preferred junction box is either fiberglass or plastic. Panels should be mounted in NEMA type 12 enclosure with stainless steel hinges and padlock handle. If required, the panel should have legs as shown in Exhibit B, sheet E-4.

2.14. Grounding

The ground system of any marine facility is very important. The NEC requires the neutral and ground to be bonded together at the service and to a ground rod not less than 8'-0" long. A separately derived neutral and ground system as shown in Exhibit B, sheets E-5 and E-7 should be grounded to a separate heavy duty copper pipe (minimum 3/4" x 8'-0") to salt water. A copper clad steel ground rod will deteriorate in salt water. According to NEC 555-7b, the ground conductor is required to be insulated and completely separate from the neutral except at the service or a separately derived system. The ground circuit as a minimum should be grounded with bare stranded conductor of a size not less than the feeder to salt water at all distribution panels and at the end of each float. The preferred solution is to reinforce the ground system at each pedestal with bare #2 stranded copper to salt water. The purpose is to insure that all vessels connected are at equal potential and that any stray circulating current from a vessel will be shunted back to the vessel rather than to some distant vessel. It is also recommended that a metal gangway be grounded on each side either to salt water or to a steel member for fault protection of the service or feeder cable.

2.15. Ground Fault Interrupter (GFI)

Household or swimming pool ground fault interrupters (GFI) are normally set at 5 milliamps or .005 amperes. In a salt water environment, there is sufficient leakage to trip a branch circuit breaker and a GFI is therefore not recommended.

A ground fault relay such as Square D type GA set for 5 amperes has been used in the main panel to detect a current flow in the ground wire. The relay is connected with a visible green light for no fault and a red light for fault. The relay is not connected to trip the main circuit breaker. While the relay is a useful tool to detect an improperly wired vessel, some harbormasters have had the relay disconnected to avoid the "red light always on" rather than locating the vessel that is improperly connected. A 5 ampere current flow in a #2 ground wire at 200 feet will result in a voltage drop in the conductor of 1 volt. This voltage drop will result in a voltage differential between vessels and contribute to stray current corrosion.

Note: The red light signal on a ground fault relay should never be disabled as a nuisance; it indicates a potentially serious problem which needs to be isolated and corrected.

2.16. Grid Power

If a gridiron is a part of the project, electrical power is generally provided. A standard 120v., 20 amp. marine type receptacle in a cast brass box such as Russellstoll #3920G mounted adjacent to each approach ladder above extreme high tide is required. It is recommended that each outlet be protected by a ground fault interrupter (GFI) and a publicly accessible circuit breaker.

2.17. Submarine Cable Application

Where no above water routing is available, type W double neoprene jacketed cable has been used under water with depths of less than 100 feet and a relatively smooth bottom. After 3 months on the bottom, test samples of type W cable do not appear affected by crab or other marine life.

If the bottom is rocky, uneven or subject to wave action, a submarine cable is recommended. Armored submarine cable is more costly than type W cable and requires a longer time frame to acquire.