
# An Introduction to Tropical Engineering: Mechanical, Electrical & Miscellaneous Systems

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## 1. MECHANICAL

**1.1 SCOPE.** This publication discusses plumbing, air conditioning, and other mechanical systems.

**1.2 GENERAL DESIGN CONSIDERATIONS.** The major design problems affecting plumbing, air conditioning, ventilation, and other mechanical systems in tropical areas include accelerated corrosion of materials due to exposure to salt-spray, condensation, and rain; and condensation on building materials, equipment, ductwork, and piping. These problems lead to subsequent problems of moisture absorption, swelling, mold, and mildew formation. These problems are compounded by the inability to maintain comfortable space conditions in buildings due to high outdoor humidity and low sensible cooling loads.

**1.3 CRITERIA AND GUIDANCE.** Refer to NTIS-A090145, Air Conditioned Buildings in Humid Climates. Guidelines for Design, Operating, and Maintenance.

**1.4 CORROSION PROTECTION.** Ensure adequate corrosion protection through the use of non-corrosive or corrosion resistant materials where practical, and through the proper treatments of materials susceptible to corrosion.

**1.5 PIPING AND FITTINGS**

**1.5.1 ABOVEGROUND PIPING.** Use non-corrosive or corrosion-resistant piping such as copper, chlorinated polyvinyl chloride (CPVC), and fiberglass for outdoor use where appropriate.

a) Paint black steel pipe exposed to the outdoors with one coat of pre-treatment wash, two coats of zinc chromate primer, and two coats of enamel paint.

b) Use plastic, fiberglass, or copper pipe hangers when suitable.

c) Ensure that all ferrous materials, when used for pipe hangers, anchors, and other supports, are hot-dipped galvanized. Touch-up joints and damaged surfaces with a field applied zinc-rich compound.

**1.5.2 BURIED PIPING.** Use non-corrosive or corrosion-resistant piping such as copper, CPVC, and fiberglass where appropriate. Ensure that steel and ductile iron piping has a factory-applied extruded polyethylene covering or is tape wrapped and cathodically protected. Do not use aluminum pipe in aviation fueling systems in alkaline soils with pH greater than 8.5 due to accelerated corrosion.

**1.6 PLUMBING FIXTURES.** Use non-corrosive fixtures such as vitreous china, stainless steel, and fiberglass where applicable. Enameled cast iron fixtures are also suitable when other alternatives are not practical. The use of enameled pressed steel fixtures is not recommended.

**1.7 DUCTWORK.** Use stainless steel for weather hoods, exhaust stacks, and vent caps. Paint galvanized steel or aluminum sheetmetal ductwork for outdoor use with one coat of polyamide epoxy primer and one coat of polyamide epoxy exterior top coat.

**1.8 AIR CONDITIONING.** Provide air conditioning by an all-air type system. The system may be a central air handling type with chilled water coils or a unitary (single or multiple) direct expansion type unit capable of controlling the dew point of the supply air for all conditions of load. When required, apply reheat centrally using recovered heat or solar. Heat recovery may be double-bundle condensers or separate, auxiliary condensers; run-around closed-loop; or refrigerant hot gas. Use electric reheat only when critical space conditions must be maintained or in variable air volume terminal units to prevent over cooling of space.

**1.8.1 SMALL SYSTEMS.** For systems up to 35 tons, use single compressors with a minimum of three-step capacity.

**1.8.2 PACKAGED UNITS.** Use packaged unitary units with multiple reciprocating compressors (not to exceed four) for systems between 35 and 100 tons. Ensure that each compressor has separate and independent refrigerant circuits, and provides multiple steps for capacity control.

**1.8.3 CHILLED WATER SYSTEMS.** Divide the cooling capacity of chilled water systems of 100 tons and greater between two chillers to ensure reliability and constant chilled water supply without temperature fluctuations, and to prevent short cycling. Ensure that the combined capacity of the two chillers does not exceed the total requirement including diversity. Consider temperature rise in supply pipe to the most remote coil to ensure proper coil dewpoint in the selection of chilled water supply temperature.

**1.8.4 DIRECT-EXPANSION SYSTEMS.** Provide the compressor, evaporator, and condenser of direct-expansion systems with necessary accessories to ensure proper oil return and uniform circuit distribution at minimum coil load. Give consideration to the need for unloading, vertical split-row coils, back pressure regulators, and hot gas bypass.

**1.8.5 COOLING TOWERS.** Select cooling towers on the basis of a 7 degree F approach temperature. Ensure that the condenser water flow is as low as possible based on the life cycle costs of fan energy versus compressor energy and consistent with the chiller manufacturer's recommendation. Towers with long hours of operation are of the draw-through type to reduce fan horsepower requirements. Provide cooling towers with an automatic blow down system and an automatic biocide/corrosion inhibitor feed system to ensure proper water treatment. Where adequate water treatment cannot be assured, consider using a closed loop condenser water system (e.g., an evaporative cooler, or an air-cooled condenser) in lieu of a cooling tower.

**1.9 MECHANICAL EQUIPMENT**

**1.9.1 LOCATION.** Locate equipment indoors whenever possible. Roof-mounted equipment is not recommended in areas prone to hurricanes and typhoons. Additionally, roof-mounted equipment creates roof construction and maintenance problems. Where roof-mounting is unavoidable, evaluate the cost effectiveness of providing roof-top equipment rooms.

**1.9.2 MATERIAL SELECTION.** Use non-corrosive materials for outdoor mechanical equipment when feasible. For example, use stainless steel, fiberglass, or ceramic in lieu of galvanized steel for cooling towers, and aluminum in lieu of steel for exhaust fans. Use copper tube/aluminum fin, copper tube/copper fin, or aluminum tube/aluminum fin evaporator and condenser coils. Provide outdoor equipment casings and condenser coils with additional coating protection.

## 1.10 CONDENSATION CONTROL

**1.10.1 INSULATION.** Prevent condensation and subsequent problems of moisture absorption, mildew and mold formation, and corrosion by ensuring that all materials and equipment operating at temperatures below the maximum ambient dewpoint temperature are properly insulated and sealed with a vapor barrier.

**1.10.2 HEAT TRANSFER ANALYSIS.** Conduct a heat transfer analysis of the temperature profiles through the typical wall and roof sections.

**1.10.3 PIPE INSULATION**. Use cellular glass in lieu of fiberglass insulation. Insulation thicknesses for piping are based on 85 degree F dry bulb and 85 percent relative humidity ambient air. Increase insulation thicknesses as required to maintain surface temperature above dewpoint of ambient air.

a) Insulate all chilled water, refrigerant suction, and condensate drain lines, including valves, strainers, and fittings when possible. Ensure that all valve stems, gauge stems, and control sensor stems are also insulated.

 

b) Provide a vapor barrier and coatings for all cold piping 60 degrees F and lower. Give special attention to the details of construction and to the specifications for the vapor barrier to ensure complete moisture and vapor seal where insulation terminates against metal hangers, anchors, and other projections through insulation on cold surfaces with vapor barriers.

c) Require that the ends of pipe insulation be sealed with a vapor barrier coating at valves, flanges, and fittings and at intervals not to exceed 15 feet on long pipe runs. Goat joints of pipe insulation with vapor barrier coating compound to ensure vapor seal of insulation sections.

d) To the maximum extent possible, install chilled water piping in accessible locations to allow for the replacement of old, deteriorated insulation. Avoid installing chilled water piping in concealed, non-air conditioned spaces, including ceilings to minimize condensation problems.

e) Provide an aluminum or stainless steel jacket on insulated piping located outdoors.

f) Use pre-insulated piping for buried chilled water, steam, and other underground piping requiring insulation.

**1.10.4 DUCTWORK INSULATION.** Insulation thicknesses for ductwork specified are also based on 85 degree F dry bulb and 85 percent relative humidity ambient air. Ensure insulation thicknesses specified will maintain surface temperature of insulation above ambient dewpoint in instances where the actual ambient temperature and humidity exceed the above conditions.

a) Insulate all supply and return air ductwork.

b) Provide insulation with vapor barrier and coating.

c) Use internal duct liner insulation in exposed outdoor ducts when possible or where there is a lack of quality installation expertise of external insulation/vapor barrier on ductwork.

d) Insulate exhaust ducts passing through concealed spaces which exhaust conditioned air, and provide with a vapor barrier in areas where the 1 percent outdoor ambient dewpoint temperature is higher than the design indoor dry bulb temperature.

**1.10.5 EQUIPMENT INSULATION.** Provide insulation with vapor barrier and coatings on all equipment associated with the chilled water, refrigeration, or air conditioning system, including chilled water pumps, air handlers and chillers.

**1.11 HUMIDITY CONTROL.** Control humidity through the use of properly designed air conditioning systems to provide adequate dehumidification.

**1.12 SYSTEM SELECTION AND SIZING.** Consider the capacity of the air conditioning system for cooling and dehumidification under full and minimum part load conditions in the design analysis. In general, use the one percent design wet bulb temperature for equipment sizing and in the calculation of the latent cooling load.

**1.12.1 SIZING.** For the locations indicated in Table 1, size the comfort air conditioning systems based on the criteria provided in the same table.

**1.12.2 COOLING COILS.** Ensure that cooling coils have adequate latent, as well as sensible, cooling capacity under full and minimum part load conditions.

**1.13 SYSTEM DESIGN CONSIDERATIONS.** Where possible, design the air conditioning system to provide cooling for the entire building as follows:

**1.13.1 GENERAL. AIR CONDITION TOILETS, CORRIDORS, CLOSETS, AND STORAGE ROOMS.** Provide circulation of conditioned air through enclosed spaces.

a) Use excess air from the air conditioned space to make up air exhausted from the bathrooms. Do not include the bathroom cooling loads in the sizing of the air conditioning equipment. Locate exhaust grilles over or close to shower areas.

b) In Guam, Philippines, and Diego Garcia and other high humidity tropical areas where the 1 percent ambient dewpoint temperature exceeds 70 degrees F, seal the mechanical equipment rooms. Size the air conditioning equipment to supply one to two air changes/hour of conditioned air to slightly pressurize the mechanical room spaces and to maintain the room conditions in the range of 80 degrees F to 85 degrees F dry bulb temperature and 50 percent to 60 percent relative humidity. Exhaust all air supplied to the mechanical spaces through room exfiltration.

c) Treat space above ceilings as a conditioned space in areas where the 1 percent ambient dewpoint temperature exceeds the indoor dry bulb temperature. Circulate conditioned air in the ceiling plenums to prevent formation of condensation.

<table>
<tr><th colspan="3">DESIGN ROOM CONDITIONS</th></tr>
<tr><td colspan="2">Location</td><td>Temp. (Dry Bulb)/ Relative Humidity</td></tr>
<tr><td colspan="2">Philippines, Guam, Diego Garcia and other areas with 1 percent ambient dewpoint temperatures equal to or greater than 70 degrees F<br><br>Areas with 1 percent ambient dewpoint less than 70 degrees F</td><td>75 degrees F/55 percent<br><br>75 degrees F/55 percent</td></tr>
<tr><th colspan="3">OUTDOOR CONDITIONS</th></tr>
<tr><td colspan="2">Location</td><td>NAVFAC P-89 Summer Design Temp. Columns</td></tr>
<tr><td colspan="2">Philippines, Guam, Diego Garcia and other areas with 1 percent ambient dewpoint temperatures equal to or greater than 70 degrees F<br><br>Areas with 1 percent ambient dewpoint less than 70 degrees F</td><td>1 percent dry bulb and 1 percent wet bulb<br><br>2-1/2 percent dry bulb and 1 percent wet bulb</td></tr>
<tr><th colspan="3">SAFETY FACTOR</th></tr>
<tr><td>All Areas</td><td colspan="2">5 percent sensible and 5 percent latent</td></tr>
<tr><th colspan="3">CONDENSER SIZING</th></tr>
<tr><td>Location</td><td>Air Temperature</td><td>Entering Refrig. Condensing Temp.</td></tr>
<tr><td>Philippines and other areas with 1 percent ambient dry bulb temperature equal to or greater than 94 degrees F</td><td>100 degrees F</td><td>120 degrees F</td></tr>
<tr><td>Guam, Diego Garcia, and other areas with 1 percent ambient dry bulb temp-erature equal to or greater than 89 degrees F and less than 94 degrees F</td><td>95 degrees F</td><td>115 degrees F</td></tr>
<tr><th colspan="3">COOLING TOWER SIZING</th></tr>
<tr><td>All Areas</td><td colspan="2">1 percent wet bulb with 7 degrees F approach</td></tr>
</table>

Table 1

Air conditioning system sizing criteria

**1.13.2 CONTROLS.** Consider the following when designing the air conditioning controls:

a) When reheat is used with systems controlling humidity, let the thermostat control the flow to the cooling coils under normal conditions. On an increase in humidity, the humidistat overrides control of the flow to the cooling coils and, simultaneously, the thermostat assumes control of the reheat coil to prevent over cooling.

b) Whenever possible, provide modulating, in lieu of on/off controls. Provide proportional-derivative-integral controls in lieu of simple proportional controls, when space temperature and humidity must be maintained within narrow limits.

c) Specify chillers and air conditioners with hot gas bypass on the last stage when the anticipated air conditioning load may drop below the lowest stage capacity of the unit.

## 1.14 DESIGN PRACTICES

**1.14.1 DESIGN ANALYSIS.** The basis of design analysis includes the use of air conditioning systems such as variable-volume constant-temperature, variable-temperature constant-volume, and terminal-air blenders. In addition to first-cost and life-cycle cost considerations, base the system on the capability of the air conditioning system to control the humidity in the conditioned spaces continuously under full-load and part-load conditions.

**1.14.2 ENERGY ANALYSIS.** Support system selection by an energy analysis computer program, where applicable, in accordance with current energy conservation design guidelines. Evaluate latent heat gain due to vapor flow through the building structure and air bypassed through cooling coils, and the dehumidification performance of the air conditioning system under varying internal and external load conditions to ensure proper system performance. The computer program includes a printout of the space temperature and relative humidity under various internal and external loads.

 

**1.14.3 OUTSIDE AIR.** Condition outside air at all times through a separate dedicated, constant-volume, central ventilation air supply system that continuously supplies dehumidified and reheated (tempered) 100 percent outside air to all occupied spaces. Use a 4-row minimum cooling coil not to exceed a maximum coil fin density of 8 fins per inch. Use a 6- or 8-row coil in lieu of a 4-row coil, if required to control dewpoint. Prevent outside air from bypassing the cooling coil. Ensure that outside air is adequate in quantity to slightly pressurize the building under most wind velocity and building exhaust conditions. The amount of outside air over exhaust air is generally in the range of 10 to 30 percent.

**1.14.4 COOLING LOAD.** In addition to calculation of the cooling load at maximum design conditions, make a cooling load calculation for the low temperature, high-humidity conditions to determine the greatest dehumidification load that may be encountered on cloudy, humid days.

**1.14.5 OTHER CONSIDERATIONS**

a) Select main cooling coils with 6 coil rows minimum and 12 fins minimum per inch where feasible. Consider selecting main cooling coils with 8 coil rows whenever possible to ensure adequate coil contact time for improved dehumidification.

b) Ensure chilled water supply temperature is low enough for proper dehumidification.

c) Keep face velocity through the cooling coils below 550 fpm. Specify intertwined or vertical split-row cooling coils in lieu of horizontal split-row cooling coils to ensure that the entire air passage area in the coil comes in contact with active cooling surfaces for proper dehumidification. Ensure that coils have low-bypass factors.

d) Select air conditioning equipment to ensure the minimum anticipated cooling load is larger than the capacity of the lowest stage of the equipment. Use multiple air conditioning units if this is not possible.

e) Keep the building under slight positive pressure by providing slightly more make up air than the amount of air exhausted through the bathroom exhausts and other exhaust systems.

f) Provide adequately sized condensate drains for all air conditioning coils and insulate the waste lines.

g) Consider the use of heat recovery to reduce operating costs.

h) Do not use economizer cycles.

i) Use draw through air handlers where possible. Locate exhaust registers as close as possible to the source of the moisture.

k) Consider the use of air cooled condensers in lieu of cooling towers.

l) Keep system and controls simple. Do not over design, especially in areas where the lack of qualified maintenance may make sophisticated systems and controls an upkeep problem.

m) For variable air volume systems, use electric- or pneumatic-powered versus system-powered variable air volume terminal boxes. Select terminal boxes so design CFM is within 75 percent maximum CFM in capacity range. Provide minimum CFM limit stop for minimum air recirculation in accordance with the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standards.

n) Do not use outside air to ventilate plenum spaces above suspended ceilings in air conditioned buildings.

## 2. ELECTRICAL

**2..1 SCOPE.** This section covers electrical materials, equipment, and installation techniques used in general construction in a tropical environment.

**2.2 GENERAL DESIGN CONSIDERATIONS.** Salt-laden air, high temperatures and relative humidity, insect infestation, and heavy rainfall are the primary causes of electrical maintenance problems and system failures in a tropical environment. In addition, during hurricanes and typhoons, driven rain and winds in excess of 100 miles per hour cause extensive damage to overhead pole lines and insufficiently protected switchgear, transformers and circuit components. The interiors of air conditioned buildings are not subject to the harsh elements of the tropical climate.

### 2.3 APPLICATION GUIDELINES

**2.3.1 EQUIPMENT.** Installing equipment under building eaves or canopies, within enclosed equipment rooms, and on the prevailing downwind sides of buildings contributes to a more durable system with less maintenance costs. Locating switchboards, panel boards, starters, motor control centers and other major electrical items indoors improves system reliability during hurricanes and typhoons and reduces the need for exotic, expensive enclosures.

**2.3.2 DISTRIBUTION.** Underground distribution and 600 volt wiring are highly recommended to ensure superior protection from hurricanes and typhoon wind damage. However, direct buried cables are difficult to replace, subject to termite damage, and are not recommended. In hurricane and typhoon areas, prestressed concrete poles are recommended as an alternative to wood poles, funds permitting.

**2.4 CONSTRUCTION/MATERIALS CONSIDERATION.** Table 2 is a comparison of stainless steel, aluminum, polyethylene, fiberglass-reinforced concrete (FRP), and copper in various environments and their relative abilities to resist corrosion.

| APPLICATION | STAINLESS STEEL | COPPER | ALUMINUM | POLY-ETHYLENE | FRP |
|---|---|---|---|---|---|
| General Outdoor | Very Good | Very Good | Very Good | Very Good | Very Good |
| Marine Outdoor | Very Good | Very Good | Good | Very Good | Very Good |
| General Industrial | Very Good | Very Good | Good | Very Good | Very Good |
| Fresh Water | Very Good | Good | Very Good | Very Good | Very Good |
| Sea Water | Very Good | Good | Fair | Very Good | Very Good |

Table 2

Corrosion resistance comparison

**2.4.1 NON-CORROSIVE MATERIALS**. Generally, use corrosion-resistant materials such as plastic, fiberglass, copper or aluminum coated steel, or anodized or copper-free aluminum for installations exposed to the elements. Where corrosion resistant materials lack sufficient physical strength, or are subject to deterioration from the sun, or are not available, provide ferrous materials with protective enclosures and coatings.

**2.4.2 ALUMINUM.** Where the use of 6061 and 6063 series aluminum alloy materials is permitted, anodize such materials after the cutting, bending, forming, and drilling of the parts are completed. The item can then be assembled. Do not use aluminum alloy where movement or contact of bearing surfaces is expected.

**2.5 UNDERGROUND FACILITIES.** Underground installations in the tropics are characterized by high salt water tables, and high earth moisture content. On small South Pacific islands, the entire underground system and embedded materials are subject to constant salt water exposure and inundation. It is not uncommon for ductlines, handholes and manholes to contain standing water throughout the year. Select materials, cables, and splices on the basis of resistance to chemical deterioration and submersion. Aluminum conduit is especially subject to corrosion from salt and coral; therefore, do not use it in underground situations. Note that underground cable is extremely susceptible to subterranean termite damage. During installation of underground cable, soil treatment with termiticide is recommended.

## 2.6 PROTECTION AGAINST HUMIDITY, MOISTURE, AND TEMPERATURE

**2.6.1 ELECTRICAL COMPONENTS.** Do not treat switches, fuses, contacts, oil-immersed transformer windings, and heater elements with fungus-resistant coating. Other materials and components which are inherently fungus-resistant or are protected by hermetic sealing need not be treated nor coated.

**2.6.2 CIRCUIT ELEMENTS (LOW TEMPERATURE RISE).** Coat circuit elements not covered above, and which have a temperature rise of not more than 75 degrees F when operating at full load, with a fungus-resistant varnish. Circuit elements include solenoids, relays, terminal and junction blocks, capacitors, and control coils.

**2.6.3 CIRCUIT ELEMENTS (HIGH TEMPERATURE RISE).** Do not coat circuit elements such as motor coils, generator and dry type transformer windings, and similar electrical components, which have a temperature rise exceeding 75 degrees F when operating at full load, with a fungitoxic compound. Instead, give such components two coats of varnish and one sealer coat. Apply the coats by the vacupressure, immersion, centrifugal or pulsating-pressure, or built-up method so as to fill all interstices in the coils and preclude the entrapment of air or moisture. The sealer coat may be applied by brushing or spraying.

**2.6.4 FERROUS ITEMS.** Where steel is necessary as a base material, use material which is galvanized, plated, or cladded. Use stainless steel, where applicable, with type specified to provide for mechanical, structural and noncorrosive characteristics. Clear epoxy coatings and metallized coatings provide satisfactory additional corrosion protection.

**2.6.5 AMBIENT TEMPERATURE.** Give due consideration to high ambient temperatures when specifying and sizing electrical equipment. Derating of components is necessary where normal operating temperatures exceed 86 degrees F, such as rooftop installations and the interiors of protective enclosures. Derate outdoor transformers in accordance with the ANSI temperature loading guides. Precautions such as ventilation fans may be necessary to assure reliable operation with long service life.

**2.7 WIRING SYSTEMS.** The climatic conditions in most tropical areas are such that all non-enclosed locations are classified as "wet" locations as defined by the National Fire Protection Association, Inc. (NFPA) No. 70, National Electrical Code (NEC).

**2.8 RACEWAYS.** Design raceway systems in accordance with the technical literature.

**2.9 CONDUITS AND FITTINGS.** On piers and in other hostile environments where galvanized steel conduits are normally specified, use PVC-jacketed galvanized steel conduits and fittings. Other documents which form a part of the specification for the plastic coated galvanized steel rigid conduits and fittings are: 1) American National Standards Institute Inc. (ANSI) Standard C80.1, 2) Specification for Rigid Steel Conduit. Zinc Coated, and 3) Underwriters' Laboratories Inc., (UL)-6, Conduit Electrical. Rigid Metal.

**2.10 ENCLOSURES AND BOXES.** Ferrous metal enclosures and boxes exposed to salt-laden air provide service for only a few years. Use cast copper-free aluminum or PVC outlet bodies or boxes in lieu of cast ferrous metal. In very severe corrosive environments, the use of stainless steel (Type 316 or 326), fiberglass enclosures, or aluminum alloy 5052 enclosures are recommended over sheet metal rain-tight enclosures. Pressed steel outlet boxes set in any concrete that is high in alkaline content are subject to corrosion. The use of non-metallic outlet boxes and non-metallic conduit is recommended.

**2.11 HIGH VOLTAGE DISTRIBUTION (ABOVE 600 VOLTS)**

**2.11.1 UNDERGROUND DISTRIBUTION.** To achieve superior protection against hurricanes, typhoons and salt-laden air, design the power distribution for underground installation, funds permitting. If direct buried cables are used, protect the cables from physical damage with route markers, treat the soil within 12 inches of the cable for termites, and install plastic polyethylene warning tapes in the trench over the cables. Ensure that all ferrous materials used in manholes or handholes are hot-dipped galvanized and coated with epoxy or bituminous paint.

**2.11.2 OVERHEAD DISTRIBUTION**

**2.11.2.1 POLES.** Poles may be wood, metal, or prestressed concrete. (The requirement for prestressed concrete poles is much more critical in hurricane and typhoon areas than in areas where these extremely high winds do not occur.) Protect all checks and cracks in wood poles and fill with a preservative grease of 10 percent pentachlorophenol or other preservative. During or immediately following pole installation, treat the soil 12 inches around and down to the base of the pole with termiticide in areas infested by termites. Ensure that wood poles are line-guyed; every fifth pole is guyed 4 ways; and pole-top transformer banks are limited to recommended sizes.

**2.11.2.2 POLE CAPS.** To minimize leaching of wood preservative and to prevent pole top decay, install pole caps on all pole tops prior to installation. Circular, low density polyethylene cover caps are commercially available. The cover caps are secured by driving a 2 inch aluminum nail through each of the tabs. Prior to securing the caps, apply a filler or preservative paste material to eliminate any air space between the pole top and the cover cap.

**2.11.2.3 CONDUCTORS.** Use aluminum AAAC conductors in lieu of Type ACSR.

**2.11.2.4 INSULATORS AND TERMINATORS.** Insulators and terminators are subject to flashover as a result of airborne salt build-up. Rate all insulators and terminators for the next higher voltage level above the system voltage. After installation, coat insulators and terminators with silicon grease for additional protection against flashover. Heat shrinkable skirt type creepage extender to provide additional flashover protection in high salt-air environments.

**2.11.2.5 HARDWARE.** Ensure that ferrous metal hardware are hot-dip galvanized, and that aluminum guys with concrete anchors are in accordance with standards.

**2.11.3 TRANSFORMERS AND SWITCHGEAR**

**2.11.3.1 DISTRIBUTION TRANSFORMERS.** Generally, use pad-mount type transformers, undercoated where installed outdoors. Use liquid-filled sealed type transformers (without the breather pipe) or dry type, totally enclosed self-cooled, for less than 600-volt application. Where transformers are located in a vault, cast core dry transformers are recommended for their inherent fungus resistance and lack of fire-rated enclosure requirement.

**2.11.3.2 SWITCHGEAR.** Enclose switchgear in metal. Include all switchgear enclosures with thermostatically controlled space heaters for humidity control. Due to fewer exposed contacts, primary vacuum breakers are recommended over air breakers or fusible interrupters. Seal control relays where provided in dusty or humid environments.

**2.11.3.3 PROTECTIVE SHELTERS.** In the tropics all ferrous items are highly susceptible to accelerated corrosion when exposed to the weather. Also, damage to the protective coating on equipment can be expected during routine operational inspection and maintenance of transformer and switchgear facilities. Furthermore, hurricane and typhoon damage reports indicate that these exterior type installations are very susceptible to damage by flying debris. Protect pad-mounted transformer and switchgear installations in hurricane- and typhoon-prone areas from the weather with a structural shed-type enclosure of either concrete or masonry.

**2.11.3.4 FIBERGLASS REINFORCED ENCLOSURES.** In areas with severe corrosion potential, provide reinforced molded one-piece fiberglass enclosures for pad-mounted switchgear and transformers if they are installed outdoors.

**2.12 SERVICE AND DISTRIBUTION (600 VOLT AND BELOW)**

 

**2.12.1 SWITCHBOARDS AND MOTOR CONTROL CENTERS.** Switchboards and motor control centers may be of the standard manufacturers design. It is recommended that all switchboards and motor control centers be installed in enclosed buildings. If installed outdoors, provide a fiberglass housing. Standard factory-finished ferrous weatherproof housings do not provide satisfactory service life.

**2.12.2 PANELBOARDS.** For panelboards use the circuit breaker type, copper bussed, located in the interior of buildings or within enclosed spaces. Use bolt-on rather than plug-on breakers to minimize contact corrosion problems. If a panelboard is located on the exterior of a building, provide a fiberglass enclosure around the panelboard. Standard rain caps on factory modified panelboards do not afford sufficient protection against driven rain.

**2.12.3 ENGINE GENERATORS.** Engine generators by their inherent critical nature must be protected from the elements by installation in an enclosed room. Exhaust pipes, mufflers and standard weatherproof housings installed outdoors will not provide satisfactory service life in a tropical environment.

**2.13 CATHODIC PROTECTION.** Provide cathodic protection for underground ferrous pipelines and storage tanks and steel (sheet) piles. Cathodic protection systems may be of the sacrificial anode, rectifier type or a combination of the two. Locate rectifier control boxes in enclosed rooms or within fiberglass enclosures with ventilation provisions where separate dedicated rooms are not available. For connections to tanks and pipelines, use the exothermic weld types to prevent contact corrosion. When performing calculations, use in-situ resistivity test results since ground resistivity in the tropics varies from high (dry coral) to very low (volcanic clay).

## 3. SPECIALTIES

**3.1 SCOPE.** This section covers louvers and vents for exterior conditions, identifying devices, sun control, toilet compartment cubicles, and toilet room accessories.

**3.2 LOUVERS AND VENTS FOR EXTERIOR CONDITIONS.** It is recommended that all louvers and vents be aluminum, 6063-TS or 3003 alloy, welded or fuse-welded frames, with an anodized coating of not less than 0.7 mil. Blades should be drainable and stormproof type. Design structural framework for wind loads occurring within the various areas of the tropical zone.

### 3.3 SIGNAGE

**3.3.1 FIBERGLASS.** These materials are fiber-reinforced, internally colored resinous plastics and will withstand most of the aggressive elements when used for exterior purposes. However, bright colors tend to fade when exposed to constant sunlight. Direct sun also causes delamination over the long run but this is not a problem for fiberglass used as signs. Fiberglass, unlike most other plastics used in signage, can be readily painted.

**3.3.2 ACRYLIC PLASTIC AND PHENOLIC.** Use these for interior purposes only.

**3.3.3 PORCELAIN ENAMEL.** Porcelain enamel can be factory baked on to either steel or aluminum. Use aluminum backing since damage to porcelain enamel over steel can be extensive (often causing the enamel frit to separate from the steel backing in an area 2 to 10 times the size of the point of impact). Use aluminum backing, specifying that the porcelain enamel be applied to both sides of the substrate and that mounting holes be made before baking to adequately protect the substrate.

**3.3.4 INSTALLATION.** For exterior applications and interior use in heavy traffic areas, firmly attach signage to structure walls with tamper-proof fasteners. Mount large exterior signs on two posts set in concrete. Adhere interior signage on doors to the door surface with waterproof silicone adhesive.

**3.3.5 COLORS.** Coordinate the colors with the manufacturer's information regarding color fastness when signs are subject to exterior environment. Coordinate exterior color selections with recommendations from the architectural master plan if one exists.

**3.4 SUN CONTROL.** Interior and exterior sun control devices are categorized as interior blinds, both metal and woven fabrics, as well as woven fiberglass screens. Limit metals for sun control devices to prefinished aluminum with a minimum thickness of 0.032 inches for recommended spans. Fiberglass woven fabric should be rot- and weather-resistant, colorfast, dimensionally and thermally stable, and fire retardant where and when required.

**3.5 TOILET COMPARTMENTS**

**3.5.1 MATERIAL SELECTION.** In consideration of the severe salt-laden air and potential rust conditions, it is recommended that only noncorrosive materials be used in toilet compartments. Recommendation includes plastic laminate covering for wood core doors, division panels and urinal screens. Cast alloy, nonferrous chrome-plated hardware, with stainless steel floor and ceiling panel fittings, are also recommended.

**3.5.2 PHENOLICS.** An acceptable alternate to plastic laminate-covered doors and partitions is a plastic covered solid plastic phenolic resin core for compartment divisions. This material is waterproof, steam-proof, rust-proof and corrosion free. Galvanized steel with a bonderized enamel finish is not recommended, especially for urinal screens.

**3.6 TOILET ROOM ACCESSORIES.** For toilet and washroom equipment, construct all units from stainless steel (with all stainless steel moving parts), welded connections where required, and with concealed mountings for vandal-proof installation. Where color is included as a requirement, specify vinyl vacuum bonded to stainless steel only, as cold-rolled steel will corrode in the tropical environment.

## 4. EQUIPMENT

**4.1 SCOPE.** This section covers food service equipment, including electrical kitchen equipment and laundry facility equipment.

**4.2 GENERAL DESIGN CONSIDERATIONS.** There are no unique tropical requirements for equipment. Note, however, that electrical equipment installed or used within non-air-conditioned areas will have a shorter life in the tropics as elements, such as terminals and contacts, will corrode much more readily. This problem can be offset to an extent by maintaining an extensive stock of replacement parts (such as motors, timers, potentiometer, and other controls) which can be readily replaced by maintenance personnel. This is costly but will ensure equipment availability. However, ultimately the effects of corrosion will become so pervasive that the equipment will have to be replaced, as it will be no longer be economically repairable.

**4.3 PRODUCT SELECTION.** Generally, equipment manufacturers do not offer a wide selection of options. Carefully examine the manufacturers' technical literature to determine what options, if any, are available and specify the appropriate equipment (such as stainless versus galvanized steel and special factory-applied coatings). Look for the manufacturers’ statements about equipment suitable for use in humid or tropical climates.

## 5. FURNISHINGS

**5.1 SCOPE.** This section covers manufactured casework.

**5.2 GENERAL DESIGN CONSIDERATIONS.** The interior portions of buildings that are properly ventilated are not as adversely affected by the tropical elements. Of major concern is the potential environmental conditions that can cause some interior surfaces, such as smooth-faced cabinet work, to be affected by fungi.

### 5.3 CONSTRUCTION/MATERIALS CONSIDERATION

**5.3.1 WOOD.** Use paint with mildewcide additives for all wood-fabricated items where paint finish is required.

**5.3.2 PROTECTIVE COATINGS.** A prefinished factory-applied protective coating is recommended especially where cabinet work may be subjected to outside environment intrusion.

**5.3.3 PARTICLE BOARD.** Because of high-humidity, do not use particle board for furniture, millwork, and cabinet work destined for use in tropical areas. Tempered or high-density hardboard is suitable for drawer bottoms. Require non-ferrous metal fasteners, fittings, and hardware wherever possible.

**5.3.4 PLASTIC LAMINATES.** Generally, plastic laminates used in cabinet work and casework perform satisfactorily in the tropics. However, thin-film decorative vinyl laminates will not; prolonged humidity causes blistering and delamination, and exposure to direct sunlight makes them fade.

## 6. SPECIAL CONSTRUCTION

**6.1 SCOPE.** This section covers pre-engineered buildings, recording instrumentation enclosures, integrated ceilings and storage tanks.

**6.2 GENERAL DESIGN CONSIDERATIONS.** For tropical areas with high airborne salt content, pre-engineered buildings with factory-applied protected coatings over galvanized steel for the roof and siding material are still susceptible to rust and corrosion. Choose the protective coating with all the prerequisites for a lasting material. Color fading, chalking and pollution resistance are among the factors to consider. Metal type enclosures for recording instruments will generally fall into the same category, though by the very nature of the instrument package, the enclosure size may be quite different. For factory-fabricated items, such as roofing, siding and special enclosures, use such items with a baked-on coating type of factory-finish.

**6.3 BUILDING PANELS AND PRE-ENGINEERED BUILDINGS.** Specify roofing and siding material which have a long-life fluorocarbon finish.

**6.4 RECORDING INSTRUMENTATION ENCLOSURES.** Specify factory-fabricated enclosures for permanently installed recording equipment for measuring such things as stresses in wind energy, solar energy, rainfall, earthquake effects, and radio frequency levels, to protect them from salt conditions.

**6.5 INTEGRATED CEILINGS.** When design parameters allow or dictate the use of an integrated ceiling, where the suspension system, the ceiling material, the lighting and air conditioning are a homogenous unit, use the design criteria for air conditioning in the tropical area. Additionally, consider the guidance for the ceiling suspension system and tile in order to provide a maintenance-free and long-lasting integrated ceiling system.

**6.6 SHIELDED ENCLOSURES.** Use either galvanized steel or non-ferrous metal elements .

**6.7 STORAGE TANKS.** Wherever possible, situate metal storage tanks above ground and out of direct contact with sand and soil. Where they must be buried, consider using fiberglass or other non-metallic types. If underground steel storage tanks must be used, assure that they are cathodically protected, together with related pipelines.