1.0 PURPOSE AND SCOPE

(5.1.1)

This standard provides the design and installation requirements for electrical raceways and flexible cords and cables for Tank Operations Contractor facilities. The general requirements are provided in the National Electrical Code (NEC) and this standard clarifies NEC requirements and provides supplementary requirements applicable to WRPS facilities. In cases of conflict between this standard and the NEC, this standard is the prevailing requirement.

This standard includes a consistent approach to engineering evaluation of: ambient temperature, and; the long-term effects of operating temperature on life expectancy of various cord or cable insulating materials, and; the suitability of a cord or cable for a specific installation. This standard shall not apply to designs completed before the date shown in the header.

This standard shall not apply to any signaling, control, or communications circuit powered exclusively from a single UL listed Class II power supply.

2.0 IMPLEMENTATION

This standard is effective on the date shown in the header.

3.0 STANDARD

(5.1.2)

Except as required by this document, electrical raceways, flexible cords, and cables shall comply with the NEC.

3.1 General

(5.1.2)

The sizes of conduits, etc. shall be indicated on the as-built drawings (e.g., within wire-run and conduit/raceway schedules and/or electrical plans).

An equipment grounding conductor wire shall be installed in every raceway that contains:

- A power feeder or branch circuit, or
- Control power exceeding 50V nominal to a device having no other grounding conductor wire.

The design shall provide conduit sealing fittings with approved sealant at the following locations:

- Where conduits pass between areas where air pressure differential must be maintained.[1]
- Where conduits pass between areas where vapor separation must be maintained (e.g., flammable gas environment on one side of the seal).

Electrical Metallic Tubing (EMT) shall not be embedded in concrete or buried in earth.

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[1] Occupancies where air pressure differential is used to assure containment or confinement.

Polyvinyl chloride (PVC) coated rigid metal conduit is the preferred material installed inside Tank Farm Areas.

PVC conduit shall not be used inside Tank Farm Areas.

3.2 Underground Raceway Systems Located Within the Tank Farm Fences

(5.1.5)

Underground Rigid Metallic Conduit (RMC) up to and including four-inch diameter shall be installed at a minimum depth of 12 inches to the top of conduit for traffic areas or a minimum depth of 6 inches in non-traffic areas.[2]

Design drawings shall identify physical routing and usage parameters for the underground raceway systems.

The minimum size of underground RMC within the tank farm fenced areas shall be one-inch in diameter.

3.3 Flexible Cords and Cables

(5.1.2, 5.1.5)

Portable or skid mounted equipment shall be wired using either fixed wiring methods, or shall comply with NEC Article 400, "Flexible Cords and Cables." Fixed wiring shall be installed wherever it is both operationally practicable and it can be installed in compliance with sections of this standard that cover fixed wiring methods. Some restrictions may apply to fixed wiring methods due to safety considerations.

Where fixed wiring is not operationally practicable or cannot be installed without incurring safety hazards, the installation shall conform to NEC Article 400, "Flexible Cords and Cables."

Wiring method shall not be based on NEC Article 590, "Temporary Installations," unless fully conforming to the activities identified in NEC Article 590.3, "Time Constraints," and are genuinely activity-based as follows:

- The temporary installation serves no purpose other than the activity that is used to define the time constraint.
- The activity has a clearly identified and fixed scope, and a fixed completion date.
- The activity inherently creates significant changes in the physical environment or the physical arrangement of the temporary installation.
- The temporary installation does not exist prior to start of the activity.
- The temporary installation is removed immediately upon completion of the activity.

NEC Article 590 temporary installations shall be limited to activities where a lack of configuration control is necessitated by the practical limitations of an activity of Construction,

[2]This is an exception to NEC burial depths. See RPP-21726.

Remodeling, Maintenance, Repair, Demolition, Emergency, Tests, Experiments, Developmental Work, or Holiday Lighting, as identified in NEC Article 590.3.

Infrared lamp industrial heating equipment wired with flexible cords or cables shall comply with NEC Article 422.48, "Infrared Lamp Industrial Heating Appliances."

Industrial appliances that are wired with flexible cord or cable shall be supplied through receptacle and plug, or supplied through a lockable disconnect switch or circuit breaker, and shall comply with applicable sections of NEC Article 422, "Appliances".

All industrial appliances that are wired with flexible cords or cables shall conform to NEC definition of 'Appliance', or shall comply with NEC Article 400.7, "Uses Permitted."

Only OSHA NRTL listed cords and cables shall be used, of the types appearing in NEC table 400.5A.

Extra-hard usage flexible cord or cable listed in NEC table 400.4 shall be used in outdoor locations.

Flexible cord or cable that has conductors too large for terminals of listed and labeled connection plugs, after sizing for temperature and voltage drop, shall not be required to include cord and plug connection if supplied through a lockable disconnect switch, but shall be connected to enclosures, machinery, etc., with appropriately-sized cord grip connectors or strain relief mesh grips as applicable.

3.4 Raceway Attached to Buildings or Immobile Outdoor Structures

(5.1.2, 5.1.5)

Above ground raceway shall be prohibited unless supported by a building or immobile structure.

Raceways requiring more than one expansion coupling per straight run shall be prohibited. (For steel conduit, 800 feet is the approximate limit for a single eight-inch expansion joint, but will vary with expansion joint capability.)

Expansion joints shall be adjusted for ambient temperature during installation so that summer and winter temperature extremes will not exceed motion limits of the expansion joint.

Appropriate flexible bonding jumpers shall be installed around expansion joints to maintain grounding paths.

3.5 Buried Raceway and Direct Buried Cable

(5.1.2, 5.1.5)

Buried raceways and cables shall be prohibited where known soil contamination could introduce excavation hazards.

Buried raceways or cables shall be prohibited where excavation could compromise a protected environment or a documented cultural resource, unless a significant safety improvement is demonstrated, documented, and agreed by all affected parties.

3.6 Overhead Wire and Cable

(5.1.2, 5.1.3, 5.1.5)

Overhead installations shall be prohibited in areas where known soil contamination could introduce excavation hazards for structural footings or pole bases.

Overhead installations shall be prohibited where likely to be visited by equipment moving earth or other heavy things.

Overhead installations shall be prohibited where excavation could compromise a protected environment or a documented cultural resource, unless a significant safety improvement is demonstrated, documented, and agreed by affected parties.

Overhead installations shall be prohibited where a free standing support structure capable of resisting wind and ice loads would increase dome loading beyond limits approved by engineering.

3.7 Flexible Cord and Cable Protection

(5.1.2, 5.1.4, 5.1.5)

Flexible cord or cable laid on-grade shall be protected from damage using vehicle route boundary markers and roped-off pedestrian areas. Only where markers and rope fences cannot provide protection from damage, cords and cables shall be protected from damage by structurally approved traffic passages (bridges or manufactured cable protectors) or physical barriers.

Cable protection design and installation requirements shall be documented on electrical drawings.

Cable inspection and testing requirements shall be documented on drawings, for outdoor cable and for any cable exposed to thermal or radiation aging hazards. These requirements shall cover:

- Testing of safety grounding conductor continuity, and
- Inspection, testing and recording of insulation hardness and fatigue.

Cable inspection and testing requirements shall include:

- Five years maximum interval.
- Immediately after being subjected to likely damage.
- After being physically relocated, before being re-energized.
- After conducting an electrical fault.
- After being overload for three hours.

Where cable protectors are used, they shall be installed per the manufacturer's instructions.

Cables entering or exiting cable protectors shall use transition devices as provided and/or recommended by the manufacturer.

Installation of cable protectors within Tank Farm fences shall be documented on the Approved Route Map Drawings required by TFC-ENG-FACSUP-C-10.

3.8 Flexible Cord and Cable Ampacity De-rating
(5.1.2, 5.1.5)

Flexible cords and cables shall be de-rated to account for reduced heat-transfer where they are installed in protective covering exceeding the lengths permitted by NEC 310.15(A)(2) where the covering can restrict air flow or expose a larger profile to solar gain.

In absence of an engineering analysis of heat transfer characteristics of the cable protection covering and the life expectancy of the cord or cable, outdoor cord or cable shall be de-rated to ambient of 113ºF plus the temperature rise above the surrounding ground temperature that is seen by the protective covering when exposed to direct summer sunlight, early afternoon.

In the absence of any measurements of cable protector temperatures, outdoor cord or cable shall be de-rated to an ambient temperature of 140ºF (60ºC) and cord or cable terminating devices shall be rated at minimum, 167ºF (75ºC) operating temperature.

For cords and cables **rated in** 30ºC ambient temperature but **operating in** ambient temperature of 140ºF (60ºC). In the absence of an engineered calculation, the following de-rating factors shall apply:

Ampacity De-rating Factor	Rated Operating Temperature of Terminating Device		
Rated Operating Temperature of Cord or Cable	60 ºC	75 ºC	90 ºC
60 ºC	0.00	0.00	0.00
75 ºC	0.00	(√1/3) = **0.58**	(√1/3) = **0.58**
90 ºC	0.00	(√1/4) = **0.50**	(√1/2) = **0.71**

See attachment A for general formulation applicable to ambient temperatures other than 140ºF (60ºC).

For cords and cables in NEC table 400.5(A), where no temperature rating is listed, the manufacturer's stated operating temperature and ampacity ratings shall be used with the above formulations and de-rating factors.

Where more than one flexible cord or cable is installed in the same protective covering, their ampacity shall be further de-rated using NEC table 400.5 for more than three current-carrying conductors.

4.0 DEFINITIONS

Appliance. Utilization equipment, generally other than industrial, that is normally built in standardized sizes or types and is installed or connected as a unit to perform one or more functions such as clothes washing, air-conditioning, food mixing, deep frying, and so forth.

Equipment. A general term, including fittings, devices, appliances, luminaires, apparatus, machinery, and the like used as a part of, or in connection with, an electrical installation.

5.0 SOURCES

5.1 Requirements

1. DOE O 252.1A, "Technical Standards Program."
2. NFPA-70, National Electrical Code (NEC).
3. TFC-ENG-FACSUP-C-10, "Control of Dome Loading."
4. TFC-OPS-OPER-C-10, "Vehicle and Dome Load Control in Tank Farm Facilities."
5. Standard Engineering Practice.

5.2 References

1. RPP-21726, "Vehicle and Equipment Access over Buried Utilities in and Around Tank Farms," Attachment N, "Conduit Burial Depths in Tank Farm Facilities."

ATTACHMENT A –TEMPERATURE DERATING CALCULATION

Temperature rise above ambient of an insulated conductor is in proportion to heat transferring through the insulation, the resistive heat generated by the power flow through the conductor, which is in proportion to the square of the electrical current carried by the conductor. The square-root of the temperature rise is in proportion to the electrical current carried by the conductor. This is true for steady-state electrical currents and temperatures. (This is not the entire story for conductors embedded in materials with a high thermal capacity, typically buried in earth or concrete, where a time lag exists between resistive heating and temperature rise – such 'load factors' can justify higher conductor ampacities as outlined in NEC Annex B.)

From the square-root relationship of temperature rise to electrical current, derating factors are listed for various ambient temperatures in NEC 310.16 and 310.17 temperature derating tables. This is easily verified for temperature ratings that are in even multiples of 15°C, because the corresponding derating factors are simple square-roots of integer ratios, 1/2, 1/3, 1/4, 2/3...

However, the NEC temperature derating tables have existed from a time when the calculation of a square root was something to behold. The tables do not cover simple circumstances where conductor temperature must be limited to something less than its rated temperature because of temperature limitations of the device on which a conductor is terminated. Related formulas appearing in NEC for engineering use are either convoluted to include absolute thermal resistance to calculate absolute ampacity from scratch, instead of derating published ampacities, or are too simplistic to account for a conductor operating temperature that is different than its rated temperature. Both cases are shown below just to reiterate the simple square-root relationship that prevails in any case – relationship between electric current and temperature rise from resistive heating. Finally, a useful formulation is shown to account for conductor operating temperature that is different from its rated temperature.

NFPA 70, National Electrical Code, 2008 Edition:

> **310.15 Ampacities for Conductors Rated 0–2000 Volts.**
> **(C) Engineering Supervision.** Under engineering supervision, conductor ampacities shall be permitted to be calculated by means of the following general formula:
>
> $$I = \sqrt{\frac{TC - (TA + \Delta TD)}{RDC(1 + YC)RCA}}$$
>
> where:
> TC = conductor temperature in degrees Celsius (°C)
> TA = ambient temperature in degrees Celsius (°C)
> ΔTD = dielectric loss temperature rise
> RDC = dc resistance of conductor at temperature TC
> YC = component ac resistance resulting from skin effect and proximity effect
> RCA = effective thermal resistance between conductor and surrounding ambient
>
> Informational Note: (NFPA 70, National Electrical Code, 2011 Edition)
> The dielectric loss temperature rise (ΔT_d) is negligible for single circuit extruded dielectric cables rated below 46 kV.

The above formulation may account for extra thermal insulation, RCA, beyond what is published in NEC ampacity tables. Examples might include fire retardant coatings, or cable protection systems.

ATTACHMENT A – TEMPERATURE DERATING CALCULATION (cont.)

The following formula comes from combining two instances of the above formula for two different electrical currents, I_1 and I_2, with identical thermal resistance values and factors, RDC, YC and RCA – two different ampacities for a cable, based on two different ambient temperatures, TA. It is NOT limited to voltages beyond 2000V -- it just appears in this section of code.

310.60 Conductors Rated 2001 to 35,000 Volts. (C) Tables. (4) Ambients Not in Tables.

$$I_2 = I_1\sqrt{\frac{TC - TA_2 - \Delta TD}{TC - TA_1 - \Delta TD}}$$

where:
I_1 = ampacity from tables at ambient TA_1
I_2 = ampacity at desired ambient TA_2
TC = conductor temperature in degrees Celsius (°C)
TA_1 = surrounding ambient from tables in degrees Celsius (°C)
TA_2 = desired ambient in degrees Celsius (°C)
ΔTD = dielectric loss temperature rise

For installations below 46kV, dielectric losses (ΔTD) are insignificant. In that case, $\Delta TD \approx 0$, the above formula may be simplified as shown here:

$$I_2 = I_1\sqrt{\frac{TC - TA_2}{TC - TA_1}}$$

where:
I_1 = ampacity from tables at ambient TA_1
I_2 = ampacity at desired ambient TA_2
TC = conductor temperature in degrees Celsius (°C)

TA_1 = surrounding ambient from tables in degrees Celsius (°C)
TA_2 = desired ambient in degrees Celsius (°C)

$TC\text{-}TA_2$ is the allowable or design operating temperature rise.
$TC\text{-}TA_1$ is the fully rated temperature rise from tables.

For conductor operating temperatures limited by the device upon which the cord or cable terminates, limited to something less than the cord or cable rated temperature, the allowable operating temperature, TC_2 is different than the rated conductor temperature rise, TC_1:

$$I_2 = I_1\sqrt{\frac{TC_2 - TA_2}{TC_1 - TA_1}}$$

where:
I_1 = ampacity from tables at ambient TA_1
I_2 = ampacity at desired ambient TA_2 and desired temperature limit TC_2
TC_1 **=** conductor temperature rating in degrees Celsius (°C).
TC_2 = conductor termination temperature rating in degrees Celsius (°C).
TA_1 = surrounding ambient from tables in degrees Celsius (°C)
TA_2 = desired ambient in degrees Celsius (°C)

This formula may be used to compute ampacity derating factors for ambient temperatures other than shown in section 3.8 of this standard, for operating temperature limits less than listed in the NEC tables, for terminating conductors on devices with lessor temperature ratings than the conductor temperature rating.