

Adverse Impacts of Wildfires on Power Industry Steel Structures

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Foreword

AMPP technical reports are intended to convey technical information or state-of-the-art knowledge regarding corrosion. In many cases, they discuss specific applications of corrosion mitigation technology, whether considered successful or not. Statements used to convey this information are factual and are provided to the reader as input and guidance for consideration when applying this technology in the future. However, these statements are not intended to be recommendations for general application of this technology and must not be construed as such.

Scope

The purpose of this report is to communicate the effects of wildfires heat and combustion products on corrosion resistance, material properties, and mechanical integrity of power transmission infrastructure and to identify next steps to research, develop, and implement future asset integrity management actions for the power industry. The report addresses the following general topics.

- Wildfire vulnerabilities and impacts
- Materials effects for steel, coatings, and concrete
- Power infrastructure risks and impacts
- Asset integrity risk assessment guidance
- Recommended industry actions
- AMPP activities proposed

A wildfire, bushfire, wildland fire or field fire is an unplanned, unwanted, and usually uncontrolled event in an area of combustible vegetation. Due to climate change, many locations in the United States and worldwide, such as Australia and even India, are subject to wildfires due to dry conditions during parts of the year. The frequency and severity of wildfires are increasing. According to the National Interagency Fire Center,⁽¹⁾ more than 10.3 million acres were burned in the U.S. in 2020, as compared with 4.7 million acres in 2019.¹ Further details are provided in the Introduction section.

Rationale

The extreme temperatures of wildfires can alter properties of structural materials and result in a reduction in mechanical/structural strength. In the case of transmission and distribution (T&D) line structures, this can lead to accelerated corrosion, or even the collapse the structures at some later time. Furthermore, wildfires can severely damage wires for grounding and cathodic protection systems.

Corrosion occurs at both above- and sub-grade portions of structures; however, in most cases the rate of underground corrosion is much higher than above-grade (atmospheric) corrosion. Steel structures exposed to these wildfires may suffer damage from the heat and smoke that could affect their reliability and longevity. It is important to point out that a structure may have preexisting corrosion or other structural damage prior to wildfire exposure, and the additional effects of high-temperature wildfire exposure may lead to catastrophic damage and structural failure. Accordingly, there is a broader need for asset integrity management both before and after fire exposure.

Galvanized coatings are zinc-based metallic coatings applied to structural steel using a variety of processes. The performance of these zinc-based coatings when subjected to fires depends on the characteristics of the galvanized coating. Loss of galvanizing without loss of strength may occur at lower temperatures and not be obvious, since such a structure would still be standing. It would, however, be subject to accelerated corrosion and weakening over time. Although temperatures in fires can easily exceed 538 °C (1,000 °F), they do not often last for durations which might compromise the integrity of a hot-dip galvanized steel structure. Therefore, the potential for coating damage exists, however, prior experience has typically found minimal fire damage on galvanized structural steel parts exposed to fires with short durations and/or non-critical temperatures.

Organic coatings and paints which may be burnt or charred due to wildfire exposure will require replacement. A possible technique to mitigate extensive damage to a coated steel structure exposed to a wildfire would be to replace

⁽¹⁾ National Interagency Fire Center, 3833 Development Ave., Boise, ID 83705-5354, www.nifc.gov.

conventional organic coatings with a type of coating known as an intumescent coating. Intumescent coatings, offer a mainstream solution to protect load-bearing structural steel systems exposed to fire and excessive heat. However, even intumescent coatings will require repair or replacement after exposure.

Concrete exposed to high temperatures such as fires has a complex behavior due to the differences in coefficient of thermal expansion of the concrete constituents including steel rebars. The mechanical properties of high-strength concrete at elevated temperatures are different than conventional concrete, particularly with regard to strength loss in the intermediate temperature range 100 °C – 400 °C (212 °F – 752 °F) and with the occurrence of explosive spalling in high strength concrete. The structural engineer should consider this strength loss in design and code specifications. Concrete foundations and structures exposed to wildfires should be reviewed by a registered professional structural engineer.

Condition assessment of structures after wildfire exposure should include visual inspections, portable non-destructive hardness testing, on-site potential measurements, on-site metallographic examination, and examination of concrete foundations. In conjunction with condition assessment, remote wildfire temperature monitoring is an excellent indicator for determining whether towers exposed to wildfires will require repair, replacement, or no action. There is a critical need to install sensors to monitor temperatures which can be used in structural strength and corrosion risk assessments.

Referenced Standards and Other Consensus Documents

The latest edition, revision, or amendment of the referenced standards in effect shall govern unless otherwise dated.

AMPP/NACE/SSPC, www.amp.org:

NACE SP0215/IEEE Std. 1839	“AMPP/IEEE Joint Standard Practice for Below-Grade Corrosion Control of Transmission, Distribution, and Substation Structures by Coating Repair Systems”
NACE SP0315/IEEE Std. 1835	“AMPP/IEEE Joint Standard Practice for Atmospheric (Above Grade) Corrosion Control of Existing Electric Transmission, Distribution, and Substation Structures by Coating Systems”
NACE SP0415/IEEE Std. 1895	“AMPP/IEEE Joint Standard Practice for Below-Grade Inspection and Assessment of Corrosion on Steel Transmission, Distribution, and Substation Structures”

ASTM, www.astm.org:

ASTM A242	“Standard Specification For High-Strength Low-Alloy Structural Steel”
ASTM A572	“Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel”
ASTM A588	“Standard Specification for High-Strength Low-Alloy Structural Steel”
ASTM E140 – 12B	“Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness”

CSA, www.csa.org:

CSA G40.20/G40.21	“General requirements for rolled or welded structural quality steel/Structural quality steel”
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IEC, www.iec.ch:

IEC TS 60815-1	“Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles”
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Introduction

A wildfire, bushfire, wildland fire or field fire is an unplanned, unwanted, and usually uncontrolled event in an area of combustible vegetation. Climate change is credited for a dramatic increase in wildfire events, along with flawed forestry/ecosystem management policies, including over-population, agriculture and poor staffing/resource allocation. By December 18, 2020, there had been about 57,000 wildfires in the U.S., compared with 50,477 in 2019, according to the National Interagency Fire Center.¹ More than 10.3 million acres were burned in the U.S. in 2020, compared with 4.7 million acres in 2019. Five of the top 20 largest California wildfires occurred in 2020. Due to the extreme drought conditions in the West, the predictions are for increasingly worse fire events. The extreme temperatures of these wildfires can cause a reduction in structural strength and even melt zinc-based galvanized coatings on steel. This can lead to accelerated corrosion, or even the collapse of lattice towers at some later time. Figure 1 is a photograph of one such wildfire approaching perilously close to power transmission structures.



Figure 1: Wildfire Approaching Close to Power Transmission Structures (Mike Eliason/AP)

Many locations in the United States and worldwide, such as Australia and even India,² are subject to wildfires due to dry conditions during parts of the year, in conjunction with poor land management and maintenance practices, such as failure to maintain rights-of-way, inadequate fire breaks and ground clearing operations. Conditions immediately leading up to and during the fire combine to create a highly combustible fuel load. These conditions include:

- Heavy grass covering due to a wet spring
- An unusually dry fall
- Decreased humidity (23% dropping to 10%)
- Unusually dry fuel (5% 1,000-hr. moisture level)
- Hot, dry, sustained and gusting high winds (25–35 mph)

On average, the flame heights of a wildfire can reach approximately 2 to 3 times the height of the material being burned and can reach temperatures of 800 °C (1,472 °F) or more. Under extreme conditions, flame heights of 50 meters or more and flame temperatures exceeding 1,200 °C (2,192 °F) could be realized. Flame front movement is fast at 6-14 miles per hour, depending on locations. Under those conditions, it was found that a structure is exposed to the high heat of the flame front for a period of between 60 – 120 seconds.

Definitions

Arcing: A high power discharge of electricity between two or more conductors.

Fine Particulate Matter ($PM_{2.5}$): Fine particulate matter in the atmosphere that reduces visibility and causes the atmosphere to appear hazy at elevated concentrations.

Flash Over: A phenomenon in which the line voltage flashes over surface contamination that impacts the function/effectiveness of insulators and other components, causing a line outage or relay operation.

Thermal Expansion Coefficient: The ratio of volume change to temperature change for a gas, liquid or solid; is generally dependent on temperature.

Young's Modulus: Also known as the modulus of elasticity or elastic modulus in tension or compression; a mechanical property that measures the tensile or compressive stiffness of a solid material when the force is applied lengthwise.

Wildfires and Transmission and Distribution Structures

Steel structures used in overhead transmission and distribution (T&D) lines (excluding substations) can be divided into two generic groups:

- Lattice towers including masts in portal and H-frame structures, as shown in Figure 2
- Poles and other type of structures with tubular design
- Both may be with or without guy-wire cable anchors

Other structures, including guyed towers and monopoles used by telecom utilities, have similar structural characteristics and vulnerability to wildfires as their counterparts in electric utilities.

Transmission and Distribution Structures and Materials

A variety of structural designs exist in each category which result in a wide range of structural features specific to different applications and service environments.

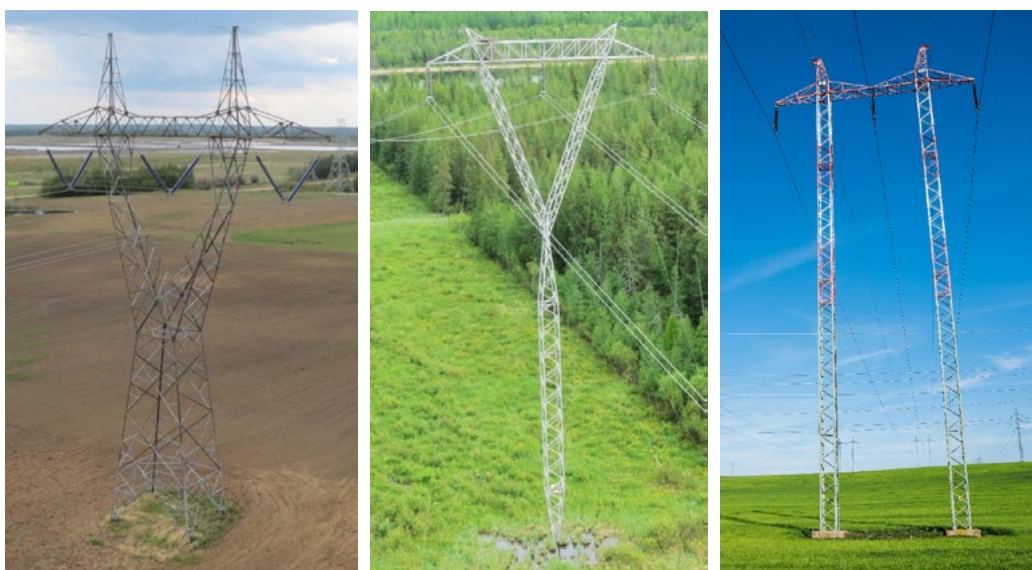


Figure 2: (Left) Lattice Structure; (Middle) Portal Structure; (Right) H-Frame Structure³