

FIRE PERFORMANCE OF LOW-SLOPE ROOF ASSEMBLIES:

Codes and Standards for the U.S. and Canada

By Marcin Pazera, PhD

Every year, fires occur in thousands of buildings in North America, resulting in property damage, injuries, and sometimes even the tragic loss of life.^{1,2} According to statistics from the National Fire Data Center, from 2014 to 2016, an estimated 100,300 non-residential building fires per year were reported to United States fire departments and caused an annual average of 90 deaths, 1,350 injuries, and \$2.4 billion in property losses.

While the causes and intensity of every

fire are different, incorporating fire protection measures and strategies during the design and construction phase can mitigate or reduce the occurrence and impact fires have on structures and their occupants. Building codes and standards were developed to address these elements—to ensure a building’s design and construction includes materials and systems that provide the greatest protection in case of a future threat from fire.

The fire performance of today’s building products and assemblies is placed under great scrutiny—and for good reason. The

structures where people live and work must be safe. For this reason, the construction industry places an emphasis on the development and continual maintenance of building codes and standards. These regulations and referenced product standards and tests provide a framework for the design and evaluation of building envelope systems and components in ways that safeguard both lives and property. And the low-slope commercial roofing industry is no exception.

The International Code Council (ICC) describes building codes as “a jurisdiction’s official statement on building safety. They are a set of minimum standards to ensure the health, safety, and welfare of the people. Codes address all aspects of building construction—fire, life safety, structural, plumbing, electrical, and mechanical. The regulation of building construction can be traced through history for more than 4000 years. Through time, people have become increasingly aware of ways to make buildings safer for occupants and [to] avoid catastrophic consequences of building-construction failures.”³

In the U.S. and Canada, construction materials and assemblies must meet strict building and fire safety code requirements. The roofing industry plays a pivotal role in mitigating the risks of fires in buildings across North America. The industry works tirelessly to develop, educate, and encourage the adoption

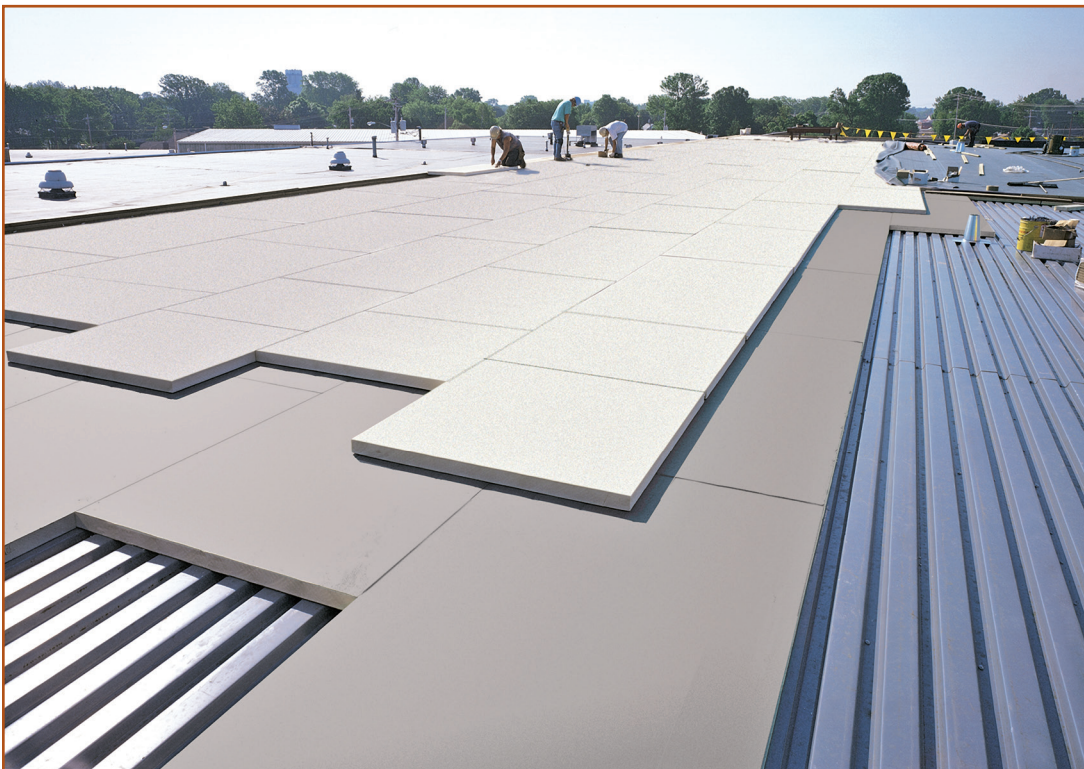


Figure 1 – Polyiso roof insulation being installed. Photo courtesy Atlas Roofing Company.



Figure 2 – The Triangle Shirtwaist Factory fire. (First published on the front page of the New York World on March 26, 1911. Wikimedia Commons.)

and enforcement of building and fire safety codes.

This article will discuss fire safety requirements in model building codes, as well as test standards used for evaluating the fire performance of commercial low-slope roof assemblies and components. Additionally, the article provides performance information on the most widely used insulation product in commercial roofing—polyisocyanurate insulation (*Figure 1*).

A BRIEF HISTORY OF FIRE SAFETY AND FIRE PROTECTION IN BUILDINGS

The utility of fire safety rules in buildings may be self-evident today. However, the industry did not arrive at the current state of affairs regarding regulations and knowledge overnight or without a variety of influences. The standards and codes used in modern construction were built on experiences and lessons learned from large fires that resulted in significant loss of life and property.

The landscape of fire safety and fire protection has also been shaped by a number of key organizations. One in particular may stand out to both industry newcomers and veterans alike: the National Fire Protection Association (NFPA). Founded in 1896, NFPA was the earliest association devoted to fire safety in buildings. A nonprofit organization since inception, NFPA was founded by a group of insurance companies in order to standardize fire sprinkler systems.⁴ The

organization continues to provide critical leadership in many issues related to building safety today.

As any individual with a few years of experience in the construction industry knows, the building code and standards have evolved over time, and continue to change each year—informed and adapted as new hazards emerge and new solutions are commercialized. Some of today’s most recognizable regulations gained widespread adoption after real-life tragedies illustrated their necessity.

Two historical examples include the Triangle Shirtwaist Factory fire and the General Motors Plant fire.

NFPA Life Safety Code and Automatic Exit Doors

More than a decade after the founding of NFPA, New York City experienced one of the deadliest and most studied industrial disasters in American history—the fire at the Triangle Shirtwaist Factory in 1911 (*Figure 2*). More than 600 people worked at the Triangle Shirtwaist Company, which occupied the top three floors of a 10-story building in Manhattan. To reduce thefts and unauthorized breaks during the workday, the owners locked the doors to the stairwells and exits. As the workday was ending on Saturday, March 25, 1911, a fire flared up in a scrap bin under one of the cutter’s tables on the eighth floor and quickly spread. There were four ways out of the building: two stairwells, an outside fire escape, and the elevators. The stairs were steep and narrow, as was the fire escape. The locked exits prevented escape for many workers. As a result, 146 people died in the fire. In the wake of this deadly disaster, the NFPA developed recommendations for outdoor fire escapes, fire exits, and fire drills in commercial buildings.

Roof Decks and Fire Tests of Building Construction

The development of today’s flame spread tests for commercial roof decks followed a \$35 million (not adjusted for inflation) loss caused by a fire involving rooftop asphalt and motor oil at a General Motors plant in Livonia, Michigan, in 1953 (*Figure 3*). Unprotected steel construction and a steel roof deck allowed the asphalt in the roof system to melt, drip through joints, and thereby contribute to fire spread within the building. This greatly contributed to the damage, which represented the largest

HYDROTECH

YOU CALL ME RAIN

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industrial fire loss in the United States to that date. The event exposed the fire risk to roof decks when buildings have large, open interior spaces, such as a warehouse or manufacturing facility. The roof collapse was attributed to several factors, including: the lack of firewalls and roof vents, allowing uncontrolled spread of flames and smoke in the building; inadequate sprinkler protection; and unprotected and uninsulated structural steel columns, trusses, and decking.⁵ The event led to changes in the building codes, including requirements for

separation of hazardous operations, sprinkler requirements in industrial buildings, fire coating for steel frame trusses, and automatic fire doors.

Several other large commercial and industrial fires in the U.S. led to the development of new requirements or changes to existing fire safety regulations. Over the years, the standardized test methods for evaluating the fire performance of materials and systems were also continually improved to account for new analyses and real-world results. With over a hundred years of dil-

igent work and thousands of contributing members, more than 300 codes and standards have been developed through the research, training, outreach, education, and advocacy carried out through the efforts led by NFPA and other global leaders like the ICC, UL, and Factory Mutual (FM).



OVERVIEW OF ASSEMBLY AND MATERIAL TEST STANDARDS

The fire safety codes and standards must also account for innovations in roofing materials or systems, as well as new installation practices. However, in the roofing industry, the general characteristics of fire testing have remained constant. Informed by events discussed above, the fire performance of low-slope roof assemblies is evaluated with respect to both external and internal fire exposure in addition to time-temperature resistance. These testing parameters simulate the type of fire exposure a roof may encounter during its service life, including interior building fires or exterior hazards such as maintenance or rooftop equipment servicing. Roofs may also be exposed to fire hazards originating from adjacent buildings or other environmental factors.

Assembly Testing

To evaluate the resistance of a roof system to external fire exposure, the industry uses ASTM E108, *Standard Test Methods for Fire Tests of Roof Coverings*;⁶ UL 790, *Standard for Standard Test Methods for Fire Tests of Roof Coverings*;⁷ and the latter's Canadian equivalent, CAN/ULC-S107, *Methods of Fire Tests of Roof Coverings*. The test methods provide a basis for comparing roof coverings under a simulated exterior fire. Roof coverings restricted to noncombustible decks require only the spread-of-flame test, while roof coverings used on combustible decks are evaluated for spread of flame, intermittent flame, and the burning brand test. A roof covering can achieve a Class A, B, or C classification, with Class A roof systems offering the greatest resistance to fire.

Fires can also originate in the interior of the building. Interior fires can create a risk of roof collapse, presenting a threat to both building occupants and first responders.

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Figure 3 – The Livonia, MI, GM plant fire of 1953. (Press photo.)

The spread of fire on the underside of a roof deck is a concern when buildings have large, open interior space, such as a warehouse or manufacturing facility. The threat of interior fire spread may be reduced in buildings that are more compartmentalized, such as a typical office building.

Using NFPA 276 (FM 4450), UL 1256, or CAN/ULC-S126, roof system performance is evaluated for an interior fire exposure. The passing criteria is established by a limit-of-flame spread within a designated time period.^{8,9} These tests evaluate the entire roof assembly, from deck to roof covering.

However, the test conditions and test pass criteria are different. See *Table 1*.

When evaluating roof assembly classifications, it is important to note that some naming conventions can cause confusion. For example, the difference between a “Class 1 roof” and a “Class A roof” is often misunderstood. An FM Class 1 designation means the assembly has been subjected to a series of tests in addition to external and internal fire exposure, including wind uplift resistance, water leakage resistance, foot traffic resistance, corrosion resistance, impact resistance, and susceptibility to heat

	FM 4450	UL 1256	CAN/ULC-S126
Exposed Sample Size	4 feet x 4 feet	1.48 feet x 24 feet	1.52 feet x 24 feet (converted from 465 mm x 7320 mm)
Test Duration	30 min.	30 min.	30 min.
Fuel Source/Rate (BTU/min)	Heptane/Propane / 26,400	Natural Gas / 5,000	Natural Gas / 5,122 (converted from 90 kW)
Temperature @ 10 min.	1500 degrees F	580°F (Vent and with non-combustible calibration sample)	N/A
Temperature @ 30 min.	1600 degrees F	N/A	N/A
Pass Criteria	No external flaming; no dropping of flaming particles into the furnace	Flame spread @ 10 min. less than 10 feet; Flame spread @ 30 min. less than 14 feet; subjective on thermal degradation and “combustive” damage	Flame spread @ 10 min. less than 3000 mm (9.84 feet); Flame spread @ 30 min. less than 4200 mm (13.78 feet); subjective on thermal degradation and charring
Pass Criteria, Maximum Fuel Contribution	3 min. 410 5 min. 390 10 min. 360 30 min. 285 (avg.)	N/A	N/A

Table 1.



ORDINARY ROOFS
WASTE ME



HYDROTECH ROOFS
LEVERAGE MY
POTENTIAL



damage. A full discussion of the FM Class 1 designation is beyond the scope of this article. However, information regarding specific performance requirements and tests can be found in FM 4470, *Approval Standard for Single-Ply, Polymer-Modified Bitumen Sheet, Built-Up Roof (BUR) and Liquid Applied Roof Assemblies for Use in Class 1 and Noncombustible Roof Deck Construction*.¹⁰ A “Class A” rating designates the highest resistance to external fire exposure only and is determined by tests specified in ASTM E108 (UL 790) or CAN/ULC-S107 standards. The sections below discuss how the building codes treat these roof assembly classifications.

Material Component Testing

Individual roof assembly component materials may also be required to undergo fire testing. Most commonly referenced is ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, which assesses two key fire burning characteristics: flame spread and smoke development. ASTM E84 utilizes the “Steiner Tunnel” and involves installing a sample of material 20 in. wide and 25 ft. long at the ceiling of the horizontal test chamber. The material is exposed to a gas flame on one end of the tunnel for a period of 10 minutes.

The rate of flame growth on the underside of the specimen is compared to selected standards. Calculations are then made to

produce a Flame Spread Index (FSI) for the material. The concentration of smoke from the fire exposure in the tunnel is also measured in the exhaust stack via a light beam to establish a Smoke Development Index (SDI) for the material. Finally, ASTM E84 has a number of other designations, such as UL 723, NFPA 255, or CAN/ULC-S102.

OVERVIEW OF BUILDING CODE REQUIREMENTS

The building code sets the minimum requirements for roof assembly performance. However, it is important to determine whether more stringent requirements apply to the project. For example, the building owner’s insurance company may require roof

POLYISOCYANURATE ROOF INSULATION PERFORMANCE

All construction materials, including foam plastics materials such as polyisocyanurate (or “polyiso”) insulation, must provide a suitable margin of fire safety. Polyiso insulation possesses a high level of inherent fire resistance when compared to other foam plastic insulations, due to its unique structure of strong isocyanurate chemical bonds. These bonds result in improved resistance to high temperature exposure, as well as enhanced fire resistance. In addition, because polyiso is a thermoset material, it does not melt or drip when exposed to flame. Polyiso forms a protective surface char when exposed to a flame, which resists the propagation of fire across the material (flame spread). This physical property is exhibited in the ASTM E84 or “Steiner Tunnel” test, where polyiso insulation test specimens remain intact during the test’s fire exposure.

The facer used with the polyiso insulate core can also play a role in the product’s fire resistance. As an example, ½-in.-thick polyiso is approved for UL Class A applications on a combustible deck. These approvals are for polyiso insulation products manufactured with a coated glass facer.

Importantly for roofing professionals, polyiso remains the only foam plastic insulation product for direct application to steel roof decks to earn FM Approval for Class 1 Roof Systems. As a result, direct-to-deck assemblies containing polyiso insulation meeting NFPA 276 (FM 4450) or UL 1256 can be installed without a thermal barrier. To date, hundreds of thousands of assemblies have gained approval under these test standards (Figure 4).

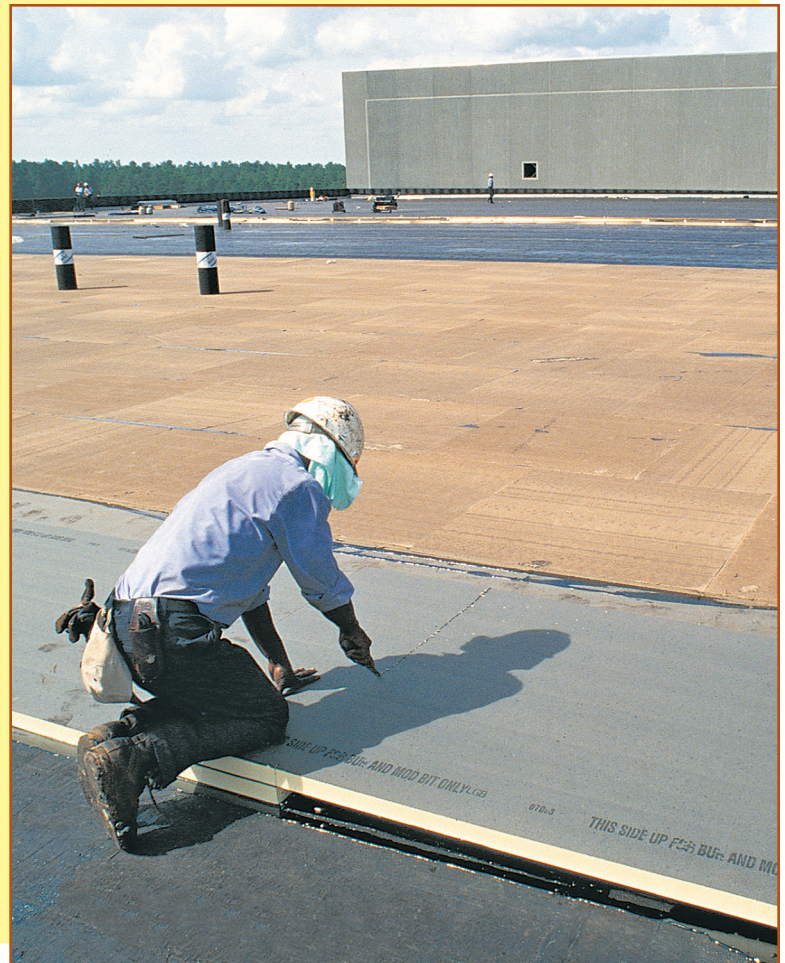


Figure 4 – Polyiso roof insulation being installed.
Photo courtesy Atlas Roofing Company.

assemblies to meet specific standards.

In the U.S., the International Building Code (IBC) is the most widely adopted model code. Developed by the ICC, the IBC is reviewed through a consensus development process every three years. The IBC, together with the International Energy Conservation Code (IECC), outline the minimum requirements for low-slope commercial roof systems.

In Canada, the National Building Code of Canada (NBCC) is published by the National Research Council (NRC) and developed by the Canadian Commission on Building and Fire Codes. Updated and published every five years, the NBCC applies to the design and construction of new buildings and alterations of existing buildings.

An overview of relevant building code provisions for the United States and Canada are provided below.

United States

IBC's Chapter 15, "Roofing," and Chapter 26, "Foam Plastics," contain the key requirements for evaluating the fire safety of low-slope insulated roof assemblies. Chapter 15 provides requirements for roof assemblies, roof coverings, and rooftop structures as they relate to fire classification, weather performance, and wind resistance. The definitions for the terms are important:

- **Roof Assembly:** A system designed to provide weather protection and resistance to design loads. The system consists of a roof covering and roof deck or a single component serving as both the roof covering and the roof deck. A roof assembly can include an underlayment, a thermal barrier, insulation, or a vapor retarder.
- **Roof Covering:** The covering applied to the roof deck for weather resistance, fire classification, or appearance.
- **Rooftop Structure:** A structure erected on top of the roof deck or on top of any part of a building.

With respect to roof assemblies, the required fire performance is determined by class and construction type. Section 1505 divides assemblies into three classes, which are determined in accordance with ASTM E108 or UL 790. Table 1505.1 contains the minimum requirements for roof covering classifications listed by types of construction.

Given today's requirements for energy efficiency, Section 1508, "Roof Insulation,"

is a critical component of the building code. While the IECC sets the minimum requirements for thermal resistance, roof insulation must also comply with the requirements in Section 1508.

Section 1508.1 permits the use of above-deck thermal insulation provided the insulation is 1) covered by an approved roof covering and 2) the roof assembly passes NFPA 276 or UL 1256. An exception applies under Section 1508.1 where a concrete roof deck is used and the above-deck insulation is covered with an approved roof covering.

However, it is important to remember that Chapter 26 requirements always apply if foam plastic insulation is used in the assembly (see IBC Section 1508.1). Polyisocyanurate insulation is the most commonly used roof insulation in the low-slope roofing market for both new construction and reroofing. Therefore, understanding how the requirements in Chapter 26 relate to fire performance is critical.

Section 2603.3, "Surface-Burning Characteristics," generally requires foam plastic insulation to have a flame spread index of not more than 75 and a smoke-developed index of not more than 450 (when tested in accordance with ASTM E84 or UL 723). However, Section 2603.3 contains an exception to this general requirement that is applicable to roof assemblies. First, the smoke-developed index is not limited for roof applications. Second, Section 2603.3 requirements do not apply where the foam plastic insulation is part of a Class A, B, or C roof-covering assembly and the assembly has passed NFPA 276 or UL 1256.

Section 2603.4, "Thermal Barrier," also provides a key requirement that applies to the use of foam plastic insulation. Generally, foam plastic insulation must be separated from the interior of the building by an approved thermal barrier (i.e., gypsum sheathing). However, Section 2603.4.1.5, "Roofing," states a thermal barrier is not required where foam plastic is 1) part of a Class A, B, or C roof-covering assembly, 2) installed in accordance with code and manufacturer's instructions, and 3) is either:

- a) Separated from the interior of the building by wood structural panel sheathing that meets the requirements of Section 2603.4.1.5.1; or
- b) Part of an assembly that passes NFPA 276 or UL 1256.

As described above, the use of foam plastic roof insulation is permitted under



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a number of scenarios. A complete understanding of the general requirements and exceptions will allow a designer or roofing professional to fully utilize the versatility of products like polyisocyanurate insulation.

Canada


The requirements for evaluating the fire safety of low-slope insulated roof assemblies can be found in Part 3 (Division B) of the NBCC.

When a building is required to be of a noncombustible construction, sections 3.1.5.14 and 3.1.5.15 describe the conditions by which foam plastic insulation can be used. The NBCC allows the use of foam plastic insulation with a flame spread index not exceeding 25 in a noncombustible construction. If its flame spread index is between 25 and 500, the foam plastic insulation is still permitted to be used, as long as it is separated from contiguous spaces by a thermal barrier.

In the specific case of low-slope roof assemblies, sections 3.1.5.3 and 3.1.15 require that all roof coverings be classified (Class A, B, or C) following CAN/ULC-S107 unless specifically covered by an exception.

CONCLUSION

Today's fire safety codes and standards have evolved over time with lessons learned

from tragedies of the past. The codes and standards that protect buildings and building occupants are continually reviewed and updated as necessary. It is important for design professionals and other key stakeholders in the construction industry to be familiar with the fire performance requirements of low-slope commercial roof assemblies. With this knowledge, a wide variety of materials can be used to construct safe and high-performing roof systems. 

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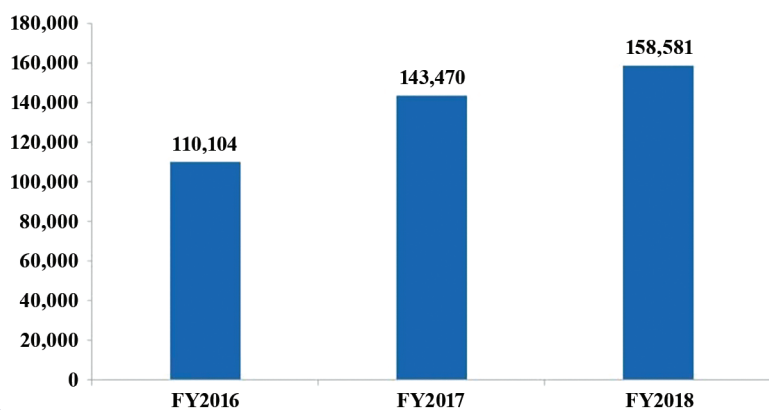
Marcin Pazera, PhD, is the technical director for the Polyisocyanurate Insulation Manufacturers Association (PIMA). Dr. Pazera coordinates all technical-related activities at PIMA and serves as the primary technical liaison

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ICE ENFORCEMENT AND RAIDS STEPPING UP

Immigration and Customs Enforcement (ICE) I-9 audits and raids on workplaces to arrest illegal immigrants have reached the highest numbers since 2014. Approximately 8000 I-9 audits of U.S. workplaces—four times the number issued in 2017—occurred in 2018. An I-9 audit is a review of an employer's I-9 forms, required on each employee upon hire to establish that the individual is eligible to work in the U.S.

Figure 1. FY2016 – FY2018 ERO Administrative Arrests



<https://www.ice.gov/doclib/about/offices/ero/pdf/eroFY2018Report.pdf>

ICE.gov claims 256,085 illegal aliens were removed from the country and 158,581 “administrative arrests” occurred in 2018. An administrative arrest is the arrest of an alien for a civil violation of U.S. immigration laws, which is subsequently adjudicated by an immigration judge or through other administrative processes.

Construction companies, which employ a large number of foreign-born workers, are cautioned to conduct self-audits of their I-9s to avoid such issues. “We’re definitely going for criminal prosecutions of employers,” said an ICE agent. It is clear that continued and even increased ICE enforcement activity, especially focusing on the workplace, will proceed at least through the remainder of the Trump administration.