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TECHNICAL NOTES

Railing Height, Design, and Criteria Review

FINAL REPORT BY:

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FOREWORD

There have been a number of incidents in the past several years where a fan or individual fell over the railing which resulted in serious injury or death.¹ There are several considerations in the requirements including: design issues, human body characteristics, and other safety considerations such as fall protection mechanisms. Therefore, the Fire Protection Research Foundation initiated a study to review incidents in public assembly venues or facilities where individuals have fallen as well as the current railing height requirements and technical basis to provide this information to the NFPA 101, *Life Safety Code*, Assembly Occupancy Technical Committee for consideration.

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About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission.



[All NFPA codes and standards can be viewed online for free.](#)

NFPA's [membership](#) totals more than 65,000 individuals around the world.

¹ Minkyu Lee, A Literature Review of Emergency and Non-Emergency Events, Fire Protection Research Foundation, August 2012

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1. Introduction

There have been several incidents in the past several years where an individual fell over a guard at the edge of a seating area which resulted in serious injury or death (Lee, 2012). There are several factors that need to be considered in establishing the requirements for guards, including: design issues, human body characteristics, and other safety considerations such as fall protection mechanisms. The NFPA 101 Assembly Occupancy Technical Committee has considered and debated this topic for several years, and seeks a clear document of the relevant information to draw conclusions for possible revisions to the Life Safety Code. The railing height requirement has also not changed appreciably in the past 30 years. However, there was a subtle change in recent editions as care was taken not to refer to sight line-constrained rails as “guards”

The scope of this project is to review guard rail heights at the edge of seating areas in places of assembly. Excluded from this study are railings along stairs or behind a row of seats. Also excluded are any guards in occupancies other than places of assembly.

2. Research Plan

In conducting this research, several areas of study were examined through four sources. The codes and standards developed by the National Fire Protection Association (NFPA) and International Code Council as well as those adopted in the United Kingdom (UK) were reviewed. The research team received input from several prominent individuals in the industry as well as those who have been active in the codes and standards committees. Most of the interaction with the selected individuals was accomplished via interviews, both in person and over the phone. Additionally, some information was received by email. The third source included descriptions of incidents in the open literature. Finally, the last source included anthropometric data on people, with an emphasis on trends in recent decades.

After compiling the information from the four categories of sources, the project team identified a set of potential proposed changes to the requirements in NFPA 101 for consideration by the committee. The project team then assessed the proposed changes relative to their potential impact on reducing injuries from falls from upper seating areas and impact on the viewing experience for attendees of venues.

3. Code Review

A review of three major codes and standards were conducted. These include the National Fire Protection Association (NFPA) 101: Life Safety Code (NFPA, 2018), the International Building Code (IBC, 2018), and the Guide to Safety at Sports Grounds (the Green Guide). The guard

height requirement has also not changed appreciably in the past 30 years. Below is a list of relevant requirements from each standard.

Table 1. Minimum Height Requirements in Codes

	NFPA 101	IBC	Green Guide
Sight-constrained guards	26"	26"	31.5"
Side and back guards	42"	42"	43.3"

NFPA 101

Guards are required at the open sides of means of egress that are 30 in. or more above the floor or the finished ground level below. These guards shall not be less than 42 in. high except when one of the following apply:

- (1) existing guards within dwelling units shall not be less than 36 in. high
- (2) the guard is in an assembly occupancy

Many railing incidents occur in assembly occupancies that have their own set of guard rail requirements. Sight line-constrained rails must have a height of not less than 26 inches. Railing systems at the foot of aisles shall not be less than 36 inches high. Railing systems at cross aisles shall not be less than 26 inches high. This does not apply where the backs of seats located at the front of the aisle project 24 inches or more above the adjacent floor of the aisle. Where cross aisles exceed 30 inches above the floor or finished ground below, guards must be no less than 42 inches high. At the side and back of seating areas, guards shall be provided with a height of not less than 42 inches. A review of previous editions of NFPA 101, dating back to 2009 (NFPA 2015, NFPA 2012, NFPA 2009) indicate that railing heights have not changed in at least the last 4 editions. Correspondence from Robert Solomon suggested that railing height requirements have remained the same for much longer than the last 4 editions (Solomon 2019).

IBC

Guards shall be located along open sided walking surfaces that are located more than 30 inches measured vertically to the floor or grade below at any point. Required guards shall be not less than 42 inches high with the exception of occupancies not more than three stories above grade within individual dwelling / single family units which require guards be not less than 36 inches high. Railing systems in accordance with guard requirements and having a minimum of 26 inches shall be provided where the railing would otherwise interfere with the sightlines of immediately adjacent seating. Guards shall be designed to resist a linear load of 50 pounds per linear foot. Guards shall resist a concentrated load of 200 pounds. Intermediate rails, pickets, and posts shall be designed to resist a concentrated load of 50 pounds.

Green Guide

The Green Guide is a UK government funded standard that applies to Sporting Grounds (DCMS, 2008). It contains 11 types of barrier classifications. Each type has a horizontal imposed load that it must be able to withstand. Horizontal imposed loads should always be considered to act at a height of 1.1m (43.3 in) above the datum. For example, crush barriers for standing accommodation have horizontal imposed loads based on the angle of viewing slope and the horizontal distance between crush barriers.

Barriers within 530 mm (20.9 in.) of the front row should be 800 mm (31.5 in.) high. Barriers immediately behind a row of seats should be a minimum height of 1.1 m (43.3 in.). Barriers used to separate stairways into channels should be at least 1 m (39.4 in.) high. Considering these requirements, spectators in seated areas should have a clear, unobstructed view of the activity. This means that careful consideration should be given to the design of any barrier for seating decks, especially those within 530 mm (20.9 in.) of fixed seating.

4. Overview of Incidents

This section presents reviews of incidents that involved railings. These reports were found using Minkyu Lee's original report of, "A Literature Review of Emergency and non- Emergency Events," (Lee, 2012) as well as various news articles and reports. This review considers incidents that occurred from 1981 to 2017.

The following twenty incidents occurred in sports venues.

Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Riverfront Stadium, Cincinnati, OH (1)	April 22, 1981	0 deaths or injuries	Front row of seats in the second deck	Tried to catch a foul ball

Summary: On April 22nd, 1981 at Riverfront Stadium, the Cincinnati Reds were playing a game with the Atlanta Braves. A teenage male who was sitting in the front row of the second deck went and tried to catch a ball that got fouled out. As he was catching the ball he caught the ball and then flipped over the railing. He was able to catch himself and grip onto the railing to pull himself back up. No injuries or deaths were reported during this incident.

Source of Summary:

- 1) McKenna, D., & McKenna, D. (2017, August 02). The Kid Who Didn't Die At Riverfront Stadium. Retrieved from <https://deadspin.com/the-kid-who-didnt-die-at-riverfront-stadium-1796882505>
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Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Riverfront Stadium, Cincinnati, OH (1)	July 19, 1982	1 death, adult female	Fell 35 feet from upper deck to first row of lower level seats	Reportedly, she had been drinking

Summary: On July 19th, 1982 at Riverfront Stadium, the Cincinnati Reds were playing a game with the Pittsburgh Pirates when a 21-year-old female fell 35 feet “head first” onto the deck below her. Sources say that she had been drinking during this game. She was pronounced dead at her arrival at General Hospital.

Source of Summary:

- 1) Ap. (1982, July 20). Fan at Reds Game Dies After Fall. Retrieved from <https://www.nytimes.com/1982/07/20/sports/fan-at-reds-game-dies-after-fall.html>
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Location	Date	Death/ Injury	Where in building?	Other Factors
Comiskey Park, Chicago, IL (1) (2)	May 16, 1986	1 death, adult male	Fell 40 feet from the upper deck railing	Reportedly seen “straddling the rail”

Summary: On May 16th, 1986 at Comiskey Park, the Chicago White Sox’s were playing the Kansas City Royals. A 53-year-old male was reportedly seen “straddling the rail” during the ninth inning. He eventually fell over and fell 40 feet from the upper deck railing onto a lower deck. He was rushed to Michael Reese Hospital but was pronounced dead at the scene.

Source of Summary:

- 1) Gorman, R. M., & Weeks, D. (2015). *Death at the ballpark: More than 2,000 game-related fatalities of players, other personnel and spectators in amateur and professional baseball, 1862-2014*. Retrieved from [https://books.google.com/books?id=GQ_NCgAAQBAJ&pg=PA175&lpg=PA175&dq=comiskey park edwardjoyce&source=bl&ots=Y4qfqYpaJI&sig=ACfU3U0n5QsHOZyS5XDhFh1zpev1D2RRNg&hl=en&sa=X&ved=2ahUKEwjBqOyu9sbhAhUKn-AKHVjxCyMQ6AEwDHoECAgQAQ#v=onepage&q=comiskey park edward joyce&f=false](https://books.google.com/books?id=GQ_NCgAAQBAJ&pg=PA175&lpg=PA175&dq=comiskey+park+edwardjoyce&source=bl&ots=Y4qfqYpaJI&sig=ACfU3U0n5QsHOZyS5XDhFh1zpev1D2RRNg&hl=en&sa=X&ved=2ahUKEwjBqOyu9sbhAhUKn-AKHVjxCyMQ6AEwDHoECAgQAQ#v=onepage&q=comiskey+park+edward+joyce&f=false)
- 2) Chicago Tribune. (2018, September 04). UPPER-DECK FALL KILLS FAN AT SOX GAME. Retrieved from https://www.chicagotribune.com/news/ct-xpm-1986-05-17-8602040694-story.html?int=lat_digitaladshouse_bx-modal_acquisition-subscriber_ngux_display-ad-Interstitial_bx-bonus-story

Location	Date	Death/ Injury	Where in building?	Other Factors
Royals Stadium, Kansas City, KS (1)	April 27, 1989	1 death, adult male	Flipped over railing and fell 12 to 15 feet	Reportedly tried doing a handstand and momentum caused him to flip over railing

Summary: On April 27th, 1989 at the Royals Stadium, Kansas City were playing the New York Yankees. A 20-year-old male was reportedly trying to do a handstand when he fell over due to momentum. He flipped over a railing and landed 12 to 15 feet below onto concrete and broke his neck. He died due to the injuries.

Source of Summary:

- 1) Gorman, R. M., & Weeks, D. (2015). *Death at the ballpark: More than 2,000 game-related fatalities of players, other personnel and spectators in amateur and professional baseball, 1862-2014*. Retrieved from

https://books.google.com/books?id=GQ_NCgAAQBAJ&pg=PA175&lpg=PA175&dq=comiskey park edward joyce&source=bl&ots=Y4qfqYpaJI&sig=ACfU3U0n5QsHOZyS5XDhFh1zpev1D2RRNg&hl=en&sa=X&ved=2ahUKEwjBqOyu9sbhAhUKn-AKHVjxCyMQ6AEwDHoECAgQAQ#v=onepage&q=comiskey park edward joyce&f=false

Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Rangers Ballpark, Arlington, TX (1)	April 1, 1994	1 injury, adult female	Fell off home run porch	Taking photos, looked up, and fell

Summary: On April 1, 1994, the opening day at the new Texas Rangers' stadium, a 26-year-old female possibly lost focus while posing for a picture and fell backwards over the 30-inch railing of the upper deck of the stadium. She suffered a fractured vertebrae, two broken ribs, a broken shoulder, and six broken teeth.

Source of Summary:

- 1) Steinbach, P. (2010, July). One on One: Baseball Fan Hollye Minter Recalls Fall from Stands. Retrieved from <https://www.athleticbusiness.com/one-on-one-baseball-fan-hollye-minter-recalls-fall-from-stands.html>
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Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Pacific Bell Park, San Francisco, CA (1)	September 17, 2003	1 death, adult male	Fell 25 feet onto sidewalk	Tried to retrieve sunglasses from below

Summary: On September 17, 2003, a 35-year-old male was reportedly drinking beer with friends and leaning against the railing of his section at the San Francisco Giants' stadium, Pacific Bell Park. His sunglasses fell off the top of his head. A man passing by offered to hold them up for the victim, who is believed to have tried to climb down from the walkway by grabbing onto a light post attached to the wall and making a shorter jump from there. In a failed attempt to grab the light post, he fell over the railing landing on his head, leading to his death.

Source of Summary:

- 1) Gorman, R. M., & Weeks, D. (2015). *Death at the ballpark: More than 2,000 game-related fatalities of players, other personnel and spectators in amateur and professional baseball, 1862-2014*. Retrieved from https://books.google.com/books/about/Death_at_the_Ballpark.html?id=FoM_mAEACAAJ

Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Busch Stadium, St. Louis, MO (1)	April 21, 2009	1 injured	“Casino Queen Party Porch”	Unknown

Summary: An adult male fan attending a Cardinal’s game at Busch Stadium in Atlanta, Georgia fell from the front row of the “Casino Queen Party Porch” section over a 30-inch rail. He had substantial injuries.

Source of Summary:

- 1) Lavigne, Paula (2011). Fans Split on Stadium Safety Changes. Retrieved from http://www.espn.com/espn/otl/story/_/id/6899698/mlb-stadium-deaths-officials-raising-railings-some-fans-disagree-changes.
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Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Busch Stadium, St. Louis, MO (1)	June 26, 2009	1 injury, adult male	Fell over front row railing	Sources say he may have fainted first

Summary: On June 26, 2009, a 34-year-old male attended a St. Louis Cardinals game at Busch Stadium. It appeared that he fainted in the 92-degree heat, fell off the upper deck onto the concourse below, and landed on an empty seat. He was treated for an injury to his left shoulder, a gash to his face and other assorted minor injuries.

Source of Summary:

- 1) Press, A. (2009, June 27). Man treated for multiple injuries. Retrieved from <http://www.espn.com/mlb/news/story?id=4290983>
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Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Miller Park, Milwaukee, WI (1)	April 25, 2010	1 death, adult male	Fell 15 ft. over lower level railing	Trying to catch a ball

Summary: On April 25, 2010, a 51-year-old male attended a Milwaukee Brewers game at Miller Park. The man reached out for a foul ball during batting practice when he fell 14 feet over a lower-level railing onto hard dirt. A brain hemorrhage subsequently hospitalized him, who passed away days later.

Source of Summary:

- 1) Steinbach, P. (2010, May). Ballpark Fall Turns Fatal at Miller Park. Retrieved from <https://www.athleticbusiness.com/spectator-safety/ballpark-fall-turns-fatal.html>
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Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Rangers Ballpark, Arlington, TX (1)	July 6, 2010	1 injury, adult male	Fell over railing at section 235	Trying to catch a foul ball

Summary: On July 6, 2010, a 25 year-old adult male attended a Texas Rangers game at Rangers Ballpark in Arlington, Texas. He went for a home run ball that landed in his second-level section. He flipped over the 30-inch railing but was able to grab onto right before falling onto the lower deck seating. Texas Rangers' President Nolan Ryan said "he didn't believe [the man] jumped to get the ball, but said he probably extended himself, or reached for it, before falling over the second-deck railing." He suffered fractures to his skull, foot, and ankle.

Source of Summary:

- 1) MacMahon, T. (2010, July 07). Rangers' Ryan visits hospitalized fan. Retrieved from <http://www.espn.com/dallas/mlb/news/story?id=5361788>
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Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Staples Center, Los Angeles, CA (1) (2)	November 21, 2010	1 death, male child	Fell from a luxury box	Parents reportedly looking at photo, not at the child

Summary: A 2-year-old boy and his family attended a Lakers game at Staples Center on November 21, 2010. The boy, who spent most of the game on his mother's lap in a luxury box, fell to his death as his family was reportedly looking at a digital photo of them against the box's glass barrier that was taken moments before. The glass guardrail was only 10 inches above the food and beverage shelf in the luxury box.

Source of Summary:

- 1) [UPDATED with Staples Center Suit:] Lucas Tang, OC 2 y.o., Falls to Death at Lakers-Warriors Game. (2011, May 25). Retrieved from <https://ocweekly.com/updated-with-staples-center-suit-lucas-tang-oc-2-yo-falls-to-death-at-lakers-warriors-game-6471724/>
- 2) Coker, Matt. Staples Center and Parents of Lucas Tang Settle Suit Over Boy's Fatal Fall During Lakers Game (2015, Oct. 11). Retrieved from <https://ocweekly.com/staples-center-and-parents-of-lucas-tang-settle-suit-over-boys-fatal-fall-during-lakers-game-6781909/>

Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Soldier Field, Chicago, IL (1)	November 28, 2010	1 death, adult male	Fell 35 feet at a popular concessions spot	Some thought he ran over and jumped, hopped over the balcony to smoke a cigarette

Summary: On November 28, 2010, a 23-year-old male attended a Chicago Bears game at Soldier Field. The man was at a concessions area, a popular halftime hangout spot, when he cleared a three foot railing and fell 35 feet onto a storage building. He was declared dead shortly after being taken to a nearby hospital. Friends of the man believe he hopped over the balcony to smoke a cigarette, thinking there was a platform but was unaware of the 35 foot drop.

Source of Summary:

- 1) Archive, 6. (2010, November 29). Bears fan Stewart Haverty dies after 20-foot fall at Chicago NFL stadium | 6abc Philadelphia Archive. Retrieved from <https://6abc.com/archive/7814061/>

Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Rangers Ballpark Arlington, TX (1) (2)	2011	1 death, adult male	Fell about 20 ft into scoreboard	Trying to catch a ball

Summary: 39-year-old male attended a Texas Rangers baseball game at Rangers Ballpark in July 2011. An outfielder tossed a souvenir ball into the stands. The man caught the ball, but lost his balance and flipped over the 33-inch railing of the outfield seats. He fell about 20 feet and landed head-first on a scoreboard, suffering fatal injuries.

Source of Summary:

- 1) Funeral services Monday for fan who died at game. (2011, July 11). Retrieved from <https://www.cnn.com/2011/07/11/worldsport/sport-texas-rangers-game-death/index.html>
- 2) Memmott, M. (2011, July 08). After Fan Falls To His Death: Time To Stop Tossing Things Into Stands? Retrieved from <https://www.npr.org/sections/thetwo-way/2011/07/08/137703649/after-fan-falls-to-his-death-time-to-stop-tossing-things-into-stands>

Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Coors Field, Denver, CO (1)	May 24, 2011	1 injury, adult male	Stairwell 12 near concourse	Reportedly sliding down handrail

Summary: A 27-year-old male fell near stairwell, 12 close to the concourse at Coors Field while Colorado Rockies were playing. He was reportedly sliding down a handrail when he fell over because he lost his balance and struck his head. He was declared brain dead at the Denver Health Medical Center.

Source of Summary:

- 1) Denver Post. (2011, May 26). Coors Field fan dies after sliding down handrail. Retrieved from <https://www.denverpost.com/2011/05/26/coors-field-fan-dies-after-sliding-down-handrail/>

Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Georgia Dome, Atlanta, GA (1)	2012	1 death, adult male	“upper level of the stadium”	Reportedly cheering and not attentive to railing

Summary: A 20-year-old male, of Lenoir City, TN, fell over a 33-inch railing, falling 45 feet to the lower level of the Georgia Dome during a North Carolina State and Tennessee football game. He fell on top of another fan sitting in the tier below. A witness suggested that he might have been cheering, and then went over the top of the railing. He died from his injuries.

Source of Summary:

- 1) White, M. (2012, September 01). Fan dies after fall at football game. Retrieved from <https://www.cnn.com/2012/09/01/us/georgia-fan-dies/index.html>
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Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Bobby Dodd Stadium, Atlanta, GA (1)	September 22, 2012	1 death, adult male	Section 219	“Espinosa leaning up against the railing and flip back over it, like he thought a wall was behind him.”

Summary: A 22-year-old male was attending a game at Dodd Stadium in Atlanta, GA on September 22, 2012. He fell over a 33-inch railing near Section 219 to the ground level, and died from his injuries. A witness said that he saw the victim leaning up against the railing and suddenly flipped over it. The witness said it was as if he thought he was leaning up against a wall.

Source of Summary:

- 1) Morris, M. (2012, December 02). Man falls from upper level of Charlotte stadium during ACC Championship game. Retrieved from <https://www.ajc.com/sports/college/man-falls-from-upper-level-charlotte-stadium-during-acc-championship-game/62bBxi2mtDuZS32NJ9rbqK/>
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Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Lucas Oil Stadium, Indianapolis, IN (1)	September 8, 2013	2 injured	Section 148 and fell	Possible railing collapse

Summary: In a game with the Indianapolis Colts versus the Oakland Raiders at Lucas Oil Stadium. Two adult males were leaning on a barrier when it appeared to collapse. The two men were trying to catch a glove from one of the Raider's players but the gloves ended up falling short. Throughout the game many of the spectators said that they thought the railings were shaky. The men were taken to IU Health and Methodist Hospital.

Source of Summary:

- 1) Guerra, K. (2013, September 09). Witness says stadium railing shaky before collapse. Retrieved from <https://www.usatoday.com/story/sports/nfl/2013/09/09/witness-lucas-oil-stadium-railing-shaky-collapsed-two-injured-colts-raiders/2790127/>

Location	Date	Death/ Injury	Where in <i>building</i> ?	Other Factors
Ralph Wilson Stadium, Orchard Park, NY (1) (2)	November 17, 2013	2 injury, adult male	Fell from sliding down upper 300 deck handrail	Reportedly, 5th time sliding down railing and then he fell

Summary: A 29-year-old male reportedly slid down the handrail at Ralph Wilson Stadium and climbed back up to his seat five times before finally falling over. During his 20 to 25 foot fall he landed on another individual. The male who fell was charged with third degree assault and second- degree reckless endangerment.

Source of Summary:

1. Buffalo Bills fan who fell inside stadium guilty of assault. (2014, June 18). Retrieved from <https://www.cbsnews.com/news/buffalo-bills-fan-who-fell-from-stadium-found-guilty/>
- 2) Petchesky, B. (2014, June 18). New Video Of Bills Fan Falling From Upper Deck Leads To Conviction. Retrieved from <https://deadspin.com/new-video-of-bills-fan-falling-from-upper-deck-leads-to-1592548282>

Location	Date	Death/ Injury	Where in building?	Other Factors
Atlanta Turner Field, Atlanta GA (1) (2)	Aug 29, 2015	1 death, adult male	2nd row seat in section 401	Alcohol was likely a factor.

Summary: An adult male attended an Atlanta Braves baseball game at Turner Park seated in the upper deck. He stood up to cheer and heckle the Yankees player going up to bat. When he stood up from his seat, he lost his balance and fell over the 30-inch railing and onto a lower seating section, 50 feet below. He was pronounced dead upon arrival at a nearby hospital.

Source of Summary:

- 1) Stevens, A. (2016, September 23). Braves fan's fatal fall the third at Turner Field since 2008. Retrieved from <https://www.ajc.com/news/breaking-news/braves-fan-fatal-fall-the-third-turner-field-since-2008/ZdkEodGzSF8HvuLI0zaf2J/>
- 2) Larimer, S. (2016, April 20). Braves, MLB sued by family of man killed in 2015 Turner Field fall. Retrieved from https://www.washingtonpost.com/news/early-lead/wp/2016/04/20/braves-mlb-sued-by-family-of-man-killed-in-2015-turner-field-fall/?noredirect=on&utm_term=.cb0bb010dead

Location	Date	Death/ Injury	Where in building?	Other Factors
Wrigley Field, Chicago, IL (1)	May 16, 2017	1 death, adult male	Right field side, behind seating bowl	N/A

Summary: A 42-year-old male attended a Chicago Cubs game at Wrigley Field with his wife and colleagues as a part of a work outing. He fell over the railing at the right field side behind the seating bowl about 40 minutes after the game ended and hit his head. He was rushed to Advocate Illinois Masonic Medical Center where he passed away at 3:30 PM.

Source of Summary:

- 1) Bonesteel, M. (2017, May 18). Cubs fan dies after falling over a railing at Wrigley Field. Retrieved from https://www.washingtonpost.com/news/early-lead/wp/2017/05/18/cubs-fan-dies-after-falling-over-a-railing-at-wrigley-field/?noredirect=on&utm_term=.9e04e8a2dcf3

All of the 20 incidents identified during the 37-year period have occurred in sporting venues predominantly during baseball and football games. A list of the contributing causes to the 20 incidents is provided in Table 2. A majority of the incidents involved the affected individual leaning against a railing or acting recklessly (identified in Table 2 as “Misuse of Rails” or “Alcohol”). In the one case of someone collapsing, this may have been attributable to fainting, but the sources did not provide sufficient information to make that distinction.

Table 2. Contributing Factors of Incidents

Incident Cause	# of Incidents
Misuse of rails	7
Catching or reaching for a ball	4
Alcohol	3
Distractions	3
Photo being taken	1
Fainting	1
Collapsing	1

5. Demographics of People

Anthropometric data of men and women in 1999 compared to men and women in 2016 is provided in Tables 3 and 4 (Fryar, 2018). The age of individuals included in the survey ranged from 20 years old to 60 years old and over.

While the average height of an adult has not increased significantly over the last 17 years, the average weight and body mass index (BMI) values have all increased since 1999. Averages should be important to consider, but it is also important to consider deviations from the data. For example, for one tall and one short person with the same BMI, the taller individual will have a higher center of gravity and hence would need a taller guard.

Table 3. Body Factors of Men from 1999 to 2016

	1999	2016	Difference
Weight (lb)	189.4	197.9	+8.5
Height (in)	69.2	69.1	-0.1
Waist Circumference (in)	39	40.2	+1.2
BMI	27.8	29.1	+1.3

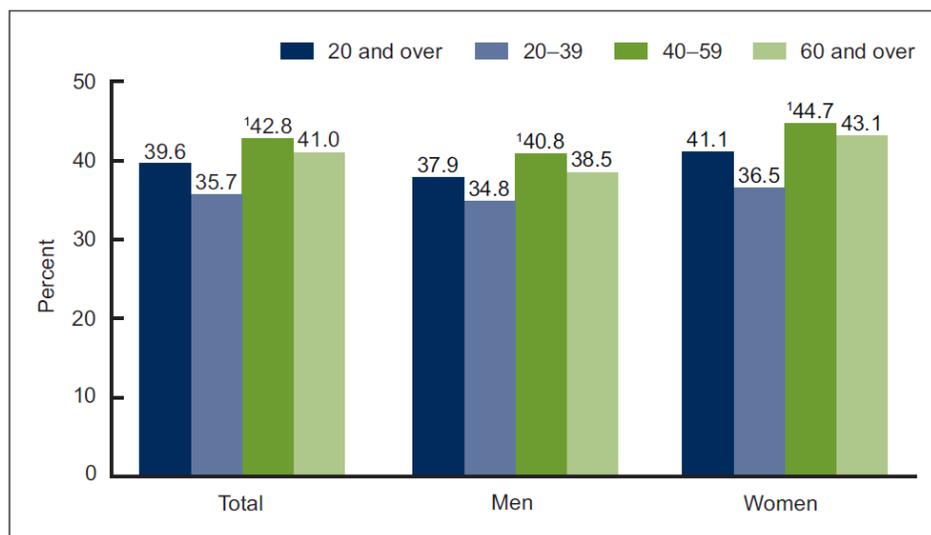
Table 4. Body Factors of Women from 1999 to 2016

	1999	2016	Difference
Weight (lb)	163.8	170.6	+6.8
Height (in)	63.8	63.7	-0.1
Waist Circumference (in)	36.3	38.6	+2.3
BMI	28.2	29.6	+1.4

The trend identified in the last 17 years is similar to that observed in the last 50 years (USDHEW 1962, CDC 2018). According to the CDC, both men and women in the United States are roughly an inch taller and 25 pounds heavier than they were in 1960, the study concludes. A measure of obesity has also jumped. BMI, or body mass index (ratio of weight (in kg) to the square of the height (in meters) has increased about 10% among adults from a value of about 25 in 1960 to 28 in 2002. Individuals are classified as being “obese” if their BMI is 30 or greater (CDC, 2019). The proportion of adults who are classified as obese varies with age, as indicated in Figure 1.

A 2007 report tested the standard deviation of anthropometric data from a 2006 World Health Organization report for individuals aged 5 to 19 years old (Mei and Grummer-Strawn, 2007). The report assigned Z-scores to height-for-age, weight-to-age, weight-for-height, and BMI-for-age. It found that the standard deviation for all metrics is in a relatively small range regardless of the mean Z-score for the country.

A study published in 2012 created anthropometric data for pregnant women in Khoy, Iran between the ages of 16 to 40 years old (Baur, 2012). Baur found that their height varied from 61.4 inches to 64 inches and their weight varied from 132 lb to 165 lb. The WHO also did a study on maternal anthropometry from 20 different countries with over 111,000 births in 1995 (Kelly). During their pregnancy, Kelly found that women gained from 17.6 lb to 30.8 lb.



¹Significantly different from those aged 20-39.

NOTES: Estimates for adults aged 20 and over were age adjusted by the direct method to the 2000 U.S. census population using the age groups 20-39, 40-59, and 60 and over. Crude estimates are 39.8% for total, 38.0% for men, and 41.5% for women.

Access data table for Figure 1 at: https://www.cdc.gov/nchs/data/databriefs/db288_table.pdf#1.

SOURCE: NCHS, National Health and Nutrition Examination Survey, 2015-2016.

Figure 1. Proportion of U.S. Adult Population Classified as Obese (Hales, et al., 2017)

The center of mass of an adult depends on the shape of the body of the adult. On average, the center of mass for adult women is proportionally 8-15% lower than for men. For men, the center of mass is typically located at the sternum (Summer, et al., 2010). The increase in weight with minimal change in height experienced for adults would suggest that the center of mass for adults may have shifted lower compared to decades ago.

6. Interviews with Key Professionals in the Industry

1) Brad Mayne

In a phone interview with Brad Mayne (CEO of the International Association of Venue Managers) on April 22, 2019, important considerations for railings were discussed as well as reaffirming similarities found in the report. Mayne had been involved in the construction of some recent arenas such as the Honda Arena in Anaheim, CA. He noted that accidents involving railings are usually in stadiums due to “active crowds” that can sometimes involve bantering between individuals or intoxication of individuals. For railings, Mayne noted that sightlines are an important factor, considering how expensive arenas are and how they have to be able to sell tickets to create profit. In some of the arena projects Mayne has participated in, he has raised the railings at least 2 inches above the minimum requirement included in NFPA 101. He has considered different types of railings and their disadvantages and advantages. Clear railings or a transparent shield can provide a high level of safety as well as a clear sightline, but they can act as sound dampers and reduce the sound quality in certain seats. Clear railings can also produce glare which can blind spectators and ruin their experience. Mayne also mentioned that railing designs for any arena should allow for flexibility, changing railings for different stadium arrangements.

2) Jake Pauls

In an in-person interview with Jake Pauls (Jake Pauls Consulting Services, member of Technical Committee on Assembly Occupancies) conducted on March 27, 2019, Pauls talked about many different incidents that involved crowd crushes and railing incidents. He directed his conversation towards incidents such as the Hillsborough Stadium Crowd Crush in Sheffield, England, the case at Atlanta Turner Field in August 2015, the Four Seasons Hall in Toronto and incidents that took place at Metro stations, particularly an incident in Washington DC's Gallery Place station where during President Obama's inauguration one person fell onto the track. Pauls also gave insight into his seating in auditoriums and thought that on balconies, swivel chairs would be beneficial right up to the guardrail. In stadiums, he suggested that since the center of gravity has gone up recently, the 42" requirement for railings is outdated and suggested a change was appropriate. He said that the IBC allows 36" for handrails where there should be a guard. He believes that this leads to bad designs as most falls would happen on stair areas and not the landings since more missteps happen at the stairs. Pauls suggested many ideas for helping sightline constraints such as in VIP sections of sports venues to add narrow or small tables to the front rows and having a flat bar to stop obstruction of sightlines as a venue in Dallas did. The tables being added to the front rows will be described in the suggested solutions section.

3) Ed Roether

In a phone call with Ed Roether (Ed Roether Consulting, LLC and member of Technical Committee on Assembly Occupancies) conducted on April 3, 2019, current railing requirements in sports venues were discussed along with possible changes that could be made. Roether pointed out that the 26-inch guard rail may not always be the railing involved with a given incident. There have been incidents in which people fall over side railings, which have a minimum height of 42 inches. He added the point that people who fall from the second row or higher may initially fall on top of people in the front row, be at an elevation where they are above the railing, and then over the railing. The height of the railing may be irrelevant if the fall starts from above the first row.

Roether added that if there is a change in the height of railings, it needs to be designed for the activities going on at the given venue. For instance, perhaps railings at baseball stadia should be higher in the event that a fan tries to reach out to catch an errant ball. Research would need to be conducted to determine what activities require what railing heights. Roether noted that consumption of alcohol can be a factor playing into railing incidents, especially in sporting venues compared to theaters.

Roether said that if he observes a stadium with a 26-inch rail, it is typically designed by someone who doesn't typically design sports facilities. He has found in his practice that typically designers will install railings taller than the minimum required height. He personally believes that 34 inches is a good height. However, railings over 26 inches will get into individuals sightlines. A clear barrier could be used; however, glass will not work since glass contains nickel sulfide, which is subject to expansion which would lead to failure of the glass. However, a clear barrier would fix the sightline issue.

4) Bill Conner

In a phone interview with Bill Conner (Bill Conner Associates, LLC, member of Technical Committee on Assembly Occupancies) conducted on April 2, 2019, railing heights in theater venues were discussed. Conner has almost 40 years of experience in theater design work, among other occupancies. He has run a consulting practice since 1982. Conner represents the theatre sector in the NFPA committee. In his experience, he has not found many incidents in theater venues. Additionally, he elaborated on the issue of sightlines in theater venues. He explained that there are limited options for guardrails in performing arts venues. The guard rails cannot be glass, as stage lights would reflect off of it. Also, the railings cannot be concave, as sound would reflect back to the stage. Conner believes that glazing would be an unacceptable solution. Conner also stated that the most important area to have adequate guardrails is the balcony. Also, in the call, areas near handicapped seating were discussed. The railings would likely be lower in this area, and he suggesting blocking off handicap seating when there are no handicapped audience members, and restricting this seating to those in wheelchairs. Despite the lack of incidents in theaters, Conner said that the 42-inch requirement is not high enough, especially where movement is not parallel with the guard in a row of seats.

7. Possible solutions

a. Increase Guard Height

As mentioned previously, some stadiums have raised their railings to at least 2 inches above the NFPA requirement of 42 inches (Larimer, 2016). However, raising the railing guard has the prospect of degrading sightlines for individuals. The American Society of Theatre Consultants performed a study on railing heights in performing art centers (Rosenbaum, 2016). In most cases, the railing height is below the average individual's center of gravity and some individuals may feel vertigo looking over the edge which can lead to a lower sense of security. While there can be a lower sense of security, businesses will have to consider sightlines as a key factor when considering into raising railing heights. In Figure 2, the railing height is shown with sightlines to the performance. The lower balcony can raise the height without significantly impacting the sightline. The upper balconies will be more significantly impacted by an increased railing height at the lower level seating areas. In order to achieve the same sightline as the lower tiers at the same height, the entire balcony will have to move backwards.

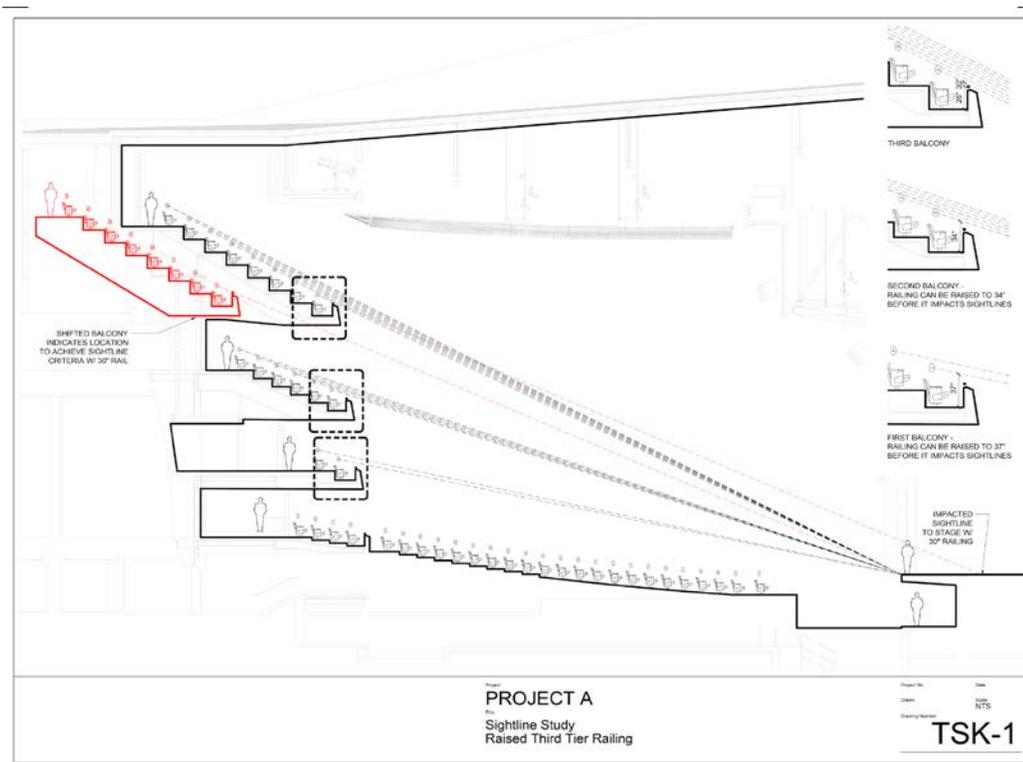


Figure 2. Red lines show the effect of raising the railing in the upper balcony area (Rosenbaum, 2019)

One example where an increased guard height could have prevented injury was at Busch Stadium in 2009. An individual had fainted during the game and had fallen over the railing. If the railing had been higher, he would not have tipped over the railing; rather, he would have collapsed onto the railing and would have slid onto the floor. Another case was in 1994 at the Rangers Ballpark. An individual was taking pictures against a 30 inch railing and had fallen over. That height could have been right around or below the area of where the center of gravity is. If that railing had been higher, her center of gravity could have been below that railing and she would not have tipped over so easily.

Raising railing height in general will be beneficial to the safety of individuals. But if it isn't possible due to a decrease in viewing experience, then raising heights at certain lower level balconies would be beneficial in increasing overall safety. Another possible solution can involve determining at what height sightlines are heavily impacted. Following that, stadiums can raise the railing height appropriately without fear of obstructing an individual's sightline.

b. Glazing Instead of Opaque Railing

One solution in lieu of opaque railings used in some venues includes a sheet of transparent glazing, such as that illustrated in Figure 3. Transparent glazing can be composed of a polymer composite and be about ½-inch thick and glazing can be any height. In some designs, a thin metal frame may surround the glazing. This eliminates the sight line issues associated with a solid railing and hence would be a significant positive feature. However, having a solid barrier will affect the sound quality received at the aisle of seats adjacent to the glazing. Furthermore, when performances include light displays, reflections off the glazing could detract from the show. Another consideration for glazing involves means for anchoring the glazing, either via slots in the structural component on the edge of the seating area or some bracket.

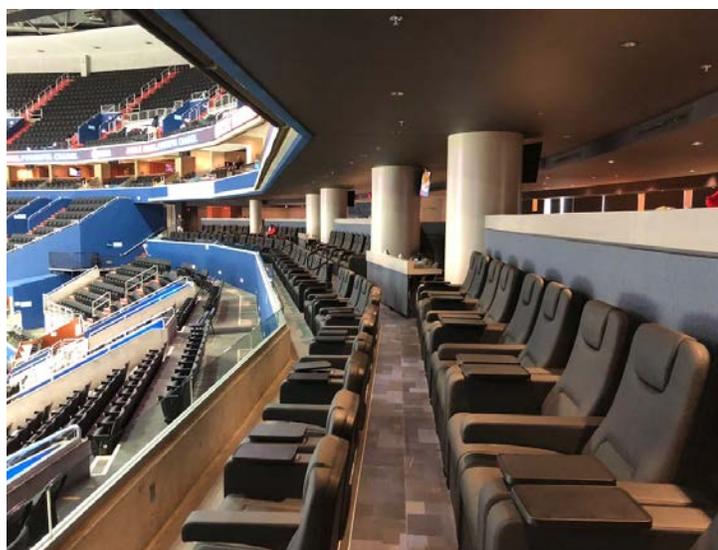


Figure 3. Glazed railing in front of box seating areas at the Capital One Center in Washington, DC (Brown, 2018)

c. Safety Net

A safety net, much like the construction safety nets depicted in Figures 4 and 5, could be installed around upper decks of stadiums. This would be a second line of protection, there to catch an individual were they to fall over a railing. A safety net could help prevent falls, especially in cases where the falling subject is able to grab and hang from the railing, such as in the incident at Riverfront Stadium in 1981. Such nets can be custom made to meet the exact shape and requirements of a given stadium. Safety nets can be made of any combination of various netting and rope. Depending on the materials used in the net, the shape of the netting itself will be different. To minimize visual obstructions, certain netting patterns can be chosen

for installation Nets such as those sold by InCord are ISO 9001 compliant, ensuring high product quality.



**Figure 4. Safety Net Around Building
(Photo by C. Lee)**



**Figure 5. Safety Net
Construction Site (InCord, 2019)**

d. Cross Section of Guardrails

It is worthwhile to consider the cross section of the top of guardrails for safety regulations. A flat cross section would obstruct the view of individuals less than a circular cross section. However, it is important to note that the width of the railings should not be too wide, as it could tempt individuals to sit on the railing or otherwise misuse it. The design of the cross section of the top of the guardrails should also take into account the individual's ability to grasp the handrail (see Figure 6). In at least one case in the review of incidents, an individual fell over the railing at Riverfront Stadium, but was able to grasp the top of the guardrail and pull himself up to safety. Because the guardrail was graspable, he did not sustain a serious injury. Therefore, the top of guardrails should be able to be grasped by individuals to act as an extra emergency safety feature.

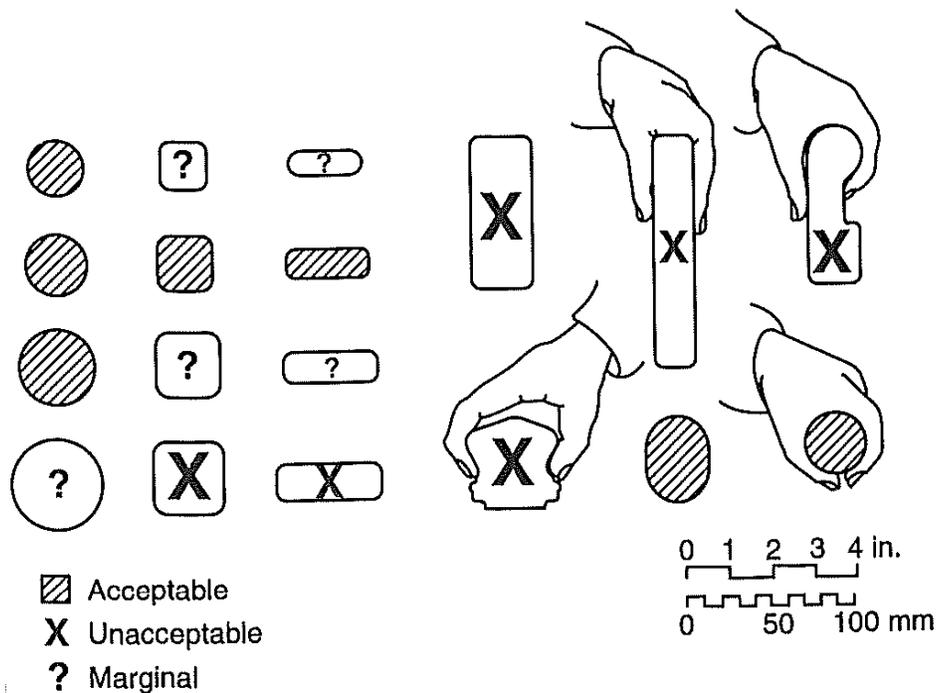


Figure 6. Cross Sections of Railings (NFPA, 2009).

e. Separating Sports Venues from other Assembly Occupancies in the Code

Separating sports venues from other assembly occupancies would be beneficial in the code because from our table, all incidents occurred in sporting venues. This separation would also be beneficial because the nature of sporting venues is unique. Peter Rosenbaum of ASTC came to the conclusion that separating sports venues from other venues would be beneficial due to the use and behaviors of the audience be completely different (Rosenbaum, 2016). Input from the interviews indicated that people in sport venues generally are more rowdy and aggressive than other types of venues. With that said however, some other types of venues may host performances that attract a crowd similar to that found in sporting venues.

The behavior of the attendees is an important characteristic because during many sports games people will stand up and lean against the railings while moving a lot. But, in other venues many people will sit back in their chairs and not use the railings as much unless for assistance with walking through the aisles. Sports venues also tend to have a higher consumption of alcohol compared to other venues. This is also a factor that can contribute to a rowdier crowd. Since the nature of sports venues typically creates a more rambunctious crowd compared to other venues, it would be advisable for sports venues to have different guard height requirements. By having different railing criteria, sports venues would be able to change their railing heights and other criteria according to their needs without affecting the requirements of other assembly occupancies. One issue with the separation is the need to clarify what must be considered a sports venue in order to ensure there are no loopholes in classification. Another con that would

arise with sports venues is that stricter railing height requirements would force many sports venue owners to fund the modification of their venue's current railings.

f. Placement of Aisle Behind Front Row Seating

One final solution could involve positioning the aisle accessway behind a seating area, or providing an increased horizontal surface, such as a table, at the edge of the seating section, such as that depicted in Figure 6. This arrangement could be a potential solution as it would restrict people from falling over the railing by having a separation distance between the aisle accessway and the edge of the seating area. A negative aspect of the arrangement with the swivel chairs illustrated in Figure 6 for facility operators is the additional space required for swivel chairs as compared to fixed seating.



Figure 6. Configuration with Aisle behind Seating (Pauls, 2019)

As an alternative, a table could also be included at the edge of the seating area (in front of the row of seats) (see Figure 7). Two negatives of this solution are concerns about sightlines and potential misuse. For people in the row of seating, sightlines may be restricted unless the railing on top of the table is relatively low. A concern about this solution is the potential of people standing on top of the table and misusing the table, which could lead to a fall over the railing. Also, having a table might decrease profits because it would take spectator room away from the stadium.



Figure 7. Table between Seating and Glazing (Pauls, 2019)

8. Summary and Areas for Future Study

Based on the research conducted, reviewing the set of incidents and interacting with a group of individuals recommended by the Project Technical Panel, the research group suggests that the following items be considered by the committee for further consideration.

- 1) Provide separate requirements for sport venues due to the unique nature of the crowds in this type of venues.
- 2) Increase the height requirement for sight-constraint guards. Further research could be conducted to determine an appropriate increase in such guards.

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