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Contact with Electricity:

An Interdisciplinary Annotated Bibliography

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2023

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Contact with Electricity: An Interdisciplinary Annotated Bibliography

Albert, A. and M. R. Hallowell (2013). "Safety risk management for electrical transmission and distribution line construction." Safety science 51(1): 118-126.

Prior research has established that electrical contractors involved in the construction and maintenance of electrical transmission and distribution (T&D) lines are at extremely high risk of electrocution. The result of inadvertent contact with T&D lines often is death or severe injury that involves damage to internal organs, musculoskeletal disorders, neurological damages and severe burns. The Electrical Safety Foundation International has demonstrated that contact with overhead power lines has been the single largest cause of electrical fatalities over the last decade. To reduce this disproportionate injury rate, electrical contractors implement many strategies such as the use of rubber insulating equipment, and locking devices. Unfortunately, these strategies are often cost-prohibitive in certain construction and maintenance scenarios. Therefore, electrical contractors are faced with complex decisions that involve comparing the cost of injury prevention with the expected safety benefit. This paper presents research that objectively evaluated the risk associated with common T&D construction tasks and the effectiveness of specific injury prevention techniques. The research team then developed a decision support framework that provides electrical contractors with objective safety and cost feedback given specific project characteristics. The results indicate that many of the effective strategies implemented to reduce T&D electrical injuries are very costly (e.g., de-energizing lines). Consequently, under most conditions, the costs of injury prevention far outweigh the cost savings associated with the reduction of injury rates. The implication of these findings is that T&D electrical contractors must highly value the non-monetary benefits of injury prevention in order to improve safety in their sector.

Albert, A., et al. (2020). "Focus on the fatal-four: Implications for construction hazard recognition." Safety science 128: 104774.

Much effort has been devoted to improving hazard recognition in the construction industry. One such effort is the training outreach program pioneered and promoted by the Occupational Safety and Health Administration (OSHA) – commonly known as the Construction Focus Four or the Construction Fatal Four program. This program which is integrated in much of the training efforts offered in the construction industry seeks to promote hazard recognition and management by focusing on the four leading causes of fatal incidents – namely falls, caught-in/between, struck-by, and electrocution (i.e., fatal-four) hazards. Given the emphasis of these hazards in most training efforts, the objective of the current research was to explore if there are any performance disparities among workers in recognizing hazards that fall under the fatal-four and the non-fatal-four hazard categories. To accomplish this research goal, more than 280 workers were recruited from 57 construction workplaces in the United States to participate in a hazard recognition activity. The results of the study reveal that workers fail to recognize a disproportionate number of safety hazards in both the fatal-four and the non-fatal-four hazard categories. However, workers are relatively more proficient in recognizing hazards in the fatal-four hazard category than the non-fatal-four hazard category. More specifically, on average, the participating workers roughly recognized 57% of the fatal-four safety hazards while only recognizing 18% of the non-fatal-four safety hazards. Collectively, these findings suggest that apart from focusing on the fatal-four hazards, training efforts must also focus on the non-fatal-four safety hazards – given the relative poor performance.

Anderson, N. J., et al. (2011). "Psychiatric diagnoses after hospitalization with work-related burn injuries in Washington State." J Burn Care Res 32(3): 369-378.

This study aims to describe workers who were hospitalized with work-related burn injuries and their psychiatric sequelae in Washington State. Psychiatric sequelae of interest were depression, posttraumatic stress disorder, and other anxiety disorders. Workers' compensation claims meeting a definition for a hospitalized burn patient from Washington State from January 2001 through April 2008 were analyzed. The resulting claims were searched for the presence of certain psychiatric diagnoses or treatment codes, and descriptive analyses performed. In Washington State during the time period, the prevalence of claims with psychiatric diagnoses after hospitalization with burn injury was 19%. Claims with psychiatric diagnoses had higher medical costs and more days of time loss than those without these diagnoses. Workers with electrical burns in the construction industry and in construction and extraction occupations had a higher proportion of psychiatric sequelae. Burns are devastating yet preventable injuries. Workers who were hospitalized with work-related burn injuries, particularly those in certain industries and occupations and those with electrical burns, are at high risk for developing serious psychiatric sequelae with major costs to both the individual and the society.

Arnoldo, B. D., et al. (2004). "Electrical injuries: a 20-year review." J Burn Care Rehabil 25(6): 479-484.

Electrical injuries continue to present problems with devastating complications and long-term socioeconomic impact. The purpose of this study is to review one institution's experience with electrical injuries. From 1982 to 2002, there were 700 electric injury admissions. A computerized burn registry was used for data collection and analysis. Of these injuries, 263 were high voltage (> or =1000 V), 143 were low voltage (<1000 V), 277 were electric arc flash burns, and 17 were lightning injuries. Mortality was highest in the lightning strikes (17.6%) compared with the high voltage (5.3%) and low voltage (2.8%) injuries, and mortality was least in electric arc injuries without passage of current through the patient (1.1%). Complications were most common in the high-voltage group. Mean length of stay was longest in this group (18.9 +/- 1.4 days), and the patients in this group also required the most operations (3 +/- 0.2). Work-related activity was responsible for the majority of these high-voltage injuries, with the most common occupations being linemen and electricians. These patients tended to be younger men in the prime of their working lives. Electrical injuries continue to make up an important subgroup of patients admitted to burn centers. High-voltage injuries in particular have far reaching social and economic impact largely because of the patient population at greatest risk, that is, younger men at the height of their earning potential. Injury prevention, although appropriate, remains difficult in this group because of occupation-related risk.

Bracken, T. D., et al. (2009). "An integrated job exposure matrix for electrical exposures of utility workers." J Occup Environ Hyg 6(8): 499-509.

Electric utility workers may be exposed to any combination of magnetic fields, electric fields, nuisance shocks (from spark discharges and continuous currents), imperceptible contact currents, and electrical injuries. Collectively these exposures are referred to as EMF Factors. Previous occupational exposure assessments have mainly characterized the magnetic field, with less attention to the electric field. Nuisance shocks and electrical injuries, though palpable, have received little to no attention. This article presents a prototype job exposure matrix that

addresses exposure to all EMF Factors taking into account job category, work environment, and occupied environment. Exposures for all factors were classified into three ordinal levels for 22 job categories. Electric and magnetic field exposures were classified by the geometric mean of daily average of personal exposure measurements. Although relatively sparse, survey data on nuisance shocks were adequate for exposure assignment by job category and indicate that the frequency of these exposures has diminished over time. The least information was available for imperceptible contact currents that are associated with electric field exposures and small contact voltages. Data for electrical injuries by job category were derived from the Electric Power Research Institute Occupational Health Surveillance Database, with exposure assignments based on combined injury rates for flash burn and electric shock/electrocution. The highest exposures for all EMF Factors are essentially limited to four job categories that work on or close to electrical equipment: (1) cable splicers, (2) electricians, (3) line workers, and (4) substation operators.

Chen, G. X., et al. (2000). "Expanded analysis of injury mortality among unionized construction workers." Am J Ind Med 37(4): 364-373.

BACKGROUND: To evaluate the utility of expanding the number and precision of injury categories used in previous occupational mortality studies, this study reanalyzed data from four previous studies of unionized construction workers (construction laborers, ironworkers, sheet metal workers, and operating engineers), by expanding the number of injury categories from 6 to 33. METHODS: Proportionate mortality ratios (PMRs) were computed using the distribution of deaths from the National Occupational Mortality Surveillance System, a mortality surveillance system from 28 states, as a comparison. A blue collar comparison group was also used in additional analyses to adjust for socioeconomic and other factors. RESULTS: This reanalysis identified significantly elevated PMRs in at least one of the four worker groups for falls, motor vehicle crashes, machinery incidents, electrocutions, being struck by falling objects, being struck by flying objects, explosions, suffocation, and water transport incidents. Limiting the comparison population to deaths among blue collar workers did not change the results substantially. CONCLUSIONS: This study demonstrates that increasing the precision of categories of death from injury routinely used in mortality studies will provide improved information to guide prevention. Am. J. Ind. Med. 37:364-373, 2000. Published 2000 Wiley-Liss, Inc.

Dan Bracken, T., et al. (2010). "Measured breakdown voltage and leakage current of line worker boots." IEEE Transactions on Power Delivery 25(1): 508-517.

Sixty-hertz breakdown voltage and leakage current for 48 pairs of used line worker boots were measured under dry and wet conditions. Line workers wear conventional work boots, hiking boots, or traditional lineman boots. The outer soles of work and hiking boots are predominantly a single molded piece, called a unisole; lineman boots generally have a separate heel nailed to the sole. Our survey found mainly (81%) unisole work and hiking boots. Laboratory measurements showed dry and wet breakdown were associated with sole and boot type but not with recent use, resoling, or estimated wear. Unisole boots had higher resistances and withstand voltages than separate-heel construction. Breakdown occurred at much lower voltages for wet conditions than for dry. Wet breakdown voltage determined the electrical integrity of boots for leakage currents of 50 mA or higher. For lower currents, leakage and boot resistance were the determining factors for minimizing risk from shocks. © 2009 IEEE.

Eiris, R., et al. (2018). "PARS: Using Augmented 360-Degree Panoramas of Reality for Construction Safety Training." Int J Environ Res Public Health 15(11).

Improving the hazard-identification skills of construction workers is a vital step towards preventing accidents in the increasingly complex working conditions of construction jobsites. Training the construction workforce to recognize hazards therefore plays a central role in preparing workers to actively understand safety-related risks and make assertive safety decisions. Considering the inadequacies of traditional safety-training methods (e.g., passive lectures, videos, demonstrations), researchers have employed advanced visualization techniques such as virtual reality technologies to enable users to actively improve their hazard-identification skills in a safe and controlled environment. However, current virtual reality techniques sacrifice realism and demand high computational costs to reproduce real environments. Augmented 360-degree panoramas of reality offers an innovative alternative that creates low-cost, simple-to-capture, true-to-reality representations of the actual construction jobsite within which trainees may practice identifying hazards. This proof-of-concept study developed and evaluated a platform using augmented 360-degree panoramas of reality (PARS) for safety-training applications to enhance trainees' hazard-identification skills for four types of sample hazards. Thirty subjects participated in a usability test that evaluated the PARS training platform and its augmented 360-degree images captured from real construction jobsites. The usability reviews demonstrate that the trainees found the platform and augmentations advantageously to learning hazard identification. The results of this study will foreseeably help researchers in developing engaging training platforms to improve the hazard-identification skills of workers.

Floyd, H. L., II (2015). "Facilitating Application of Electrical Safety Best Practices to "other" Workers." IEEE Transactions on Industry Applications 51(2): 1348-1352.

The premise of this paper is that a significant portion of the workforce has been unintentionally overlooked in some efforts to reduce electrical injuries and fatalities in North America. This paper discusses the limitations, application, and potential impact of North American standards providing measures for electrical injury and fatality prevention and protection to workers. In particular, it discusses workers who may not be considered the primary beneficiaries of the requirements in the standard NFPA70E, Standard for Electrical Safety in the Workplace. For many organizations, the focus of and improvement in electrical safety programs have largely addressed electrical workers whose primary work tasks involve construction, operation, and/or maintenance of electrical equipment. However, nearly 50% of workplace electrical injuries and fatalities are not of electrical workers. Managers and administrators, painters, truck drivers, farm workers, and grounds keepers and gardeners are among the top ten occupations having the most fatal electrical injuries. For these nonelectrical workers, the exposure to electrical hazards ranges from the use of common portable tools and appliances to unintentional contact with overhead power lines in the course of routine work activities. This paper provides methods to help facilitate the application of specific requirements in NFPA70E and CSA Z462 and other best practices to these "other" workers. © 1972-2012 IEEE.

Grant, A. and J. Hinze (2014). "Construction worker fatalities related to trusses: An analysis of the OSHA fatality and catastrophic incident database." Safety science 65: 54-62.

This study was conducted to gain a better understanding of the risks associated with truss installation in building projects. The Occupational Safety and Health Administration (OSHA) fatality and catastrophic incident database was analyzed for the years inclusive of 1990-2009. The database includes over 15,000 incidents, 211 of which pertain to trusses. The incidents were analyzed as to the number of fatalities per incident, the type of truss, the truss material, the activity taking place at the time of the accident, the release of the hoisting equipment, the initiation of the accident, the presence of bracing materials, the type of construction, the length of the trusses, the location of the incident, the type of accident (fall, caught-in/between, struck by, or electrocution), and the year the fatality occurred. Many of the accidents occurred at elevation and were initiated in large part by moving or falling objects. The study recommends that further research should focus on the stabilization of incomplete roof structures and the implementation of best practices for fall protection while performing truss-related work. © 2014 Elsevier Ltd.

Jackson, S. A. and D. Loomis (2002). "Fatal occupational injuries in the North Carolina construction industry, 1978-1994." Appl Occup Environ Hyg 17(1): 27-33.

Occupational injury is a major public health problem and the cause of high rates of fatalities. The construction industry is one of the leading industries for on-the-job fatalities. The North Carolina Medical Examiner's system was used to identify all fatal unintentional injuries that occurred on the job in the state's construction industry between 1978 and 1994. The populations at risk were estimated from the 1980 and 1990 U.S. censuses. There were 525 identified deaths. All except two decedents were male, and the majority were Caucasian (79.2%). The mean age of decedents was 39 years. Death rates were higher among older workers. The crude fatality rate for the overall study period was 15.4 per 100,000 worker-years, with higher rates found among African-Americans (22.9) than among Caucasians (14.5). Occupations within the industry with the highest rates were laborers (49.5), truck drivers (43.2), operating engineers (37.2), roofers (32.8), and electricians (29.0). Falls (26.7%), electrocutions (20.4%), and motor vehicle accidents (18.9%) were found to be the leading causes of death. These findings suggest a need for continued attention to the hazards of heights and electric currents and a need for occupational safety standards for motor vehicles. This study also suggests that the hazards facing construction laborers require further investigation.

Janicak, C. A. (2008). "Occupational fatalities due to electrocutions in the construction industry." J Safety Res 39(6): 617-621.

INTRODUCTION: Occupational fatalities due to contact with electricity account for approximately 9% of all deaths in the construction industry and is the fourth leading cause of death in this industry. METHOD: Differences in the proportions of electrocutions in the construction industry are significantly different from other industries based upon the age of the worker and the source of the electricity. RESULTS: This study found that, in the construction industry, the proportion of occupational fatalities due to contact with electric current is significantly higher for workers in the 16 to 19 years old age group. Contact with overhead power lines occurred more frequently with younger workers, while contact with electric wiring, transformers, and related equipment was found to occur more frequently with older workers. The proportion of fatalities due to this event was also found to account for a significantly greater proportion of fatalities in the construction industry overall. IMPACT ON INDUSTRY: The proportions of electrocution fatalities in the construction industry were found to be

significantly higher for younger workers when compared to all other industries. Focusing prevention measures toward younger workers who work near overhead power lines could have a significant impact upon death rates. For older workers, the focus should be on those who work on or near transformers, electrical wiring, and components. Across the construction industry, implementation of effective lockout-tagout programs, and verification of energy isolation, can prevent approximately 125 fatalities per year in the construction industry.

McCann, M. (2003). "Deaths in construction related to personnel lifts, 1992-1999." J Safety Res 34(5): 507-514.

PROBLEM: This study examined deaths of construction workers due to personnel lifts (boom-supported and scissor lifts, suspended scaffolds, and crane platforms). METHODS: Deaths of construction workers for 1992-1999 were examined using data from the Census of Fatal Occupational Injuries, a Bureau of Labor Statistics database. RESULTS: The study identified 339 deaths: 42% from boom-supported lifts; 26% from suspended scaffolds; 19% from scissor lifts; 5% from crane platforms; and 7% from unapproved lifts (e.g., forklift platforms). The main causes of death were falls (36%), collapses/tipovers (29%), and electrocutions (21%). DISCUSSION: Recommendations include: following OSHA regulations, wearing personal fall protection equipment, adequate maintenance, inspection before use, and training on the model of lift used. Precautions are also needed to prevent contact with overhead power lines. IMPACT ON INDUSTRY: The increasing popularity of boom-supported lifts and scissor lifts, both in construction and other industries, make their safety an important issue.

McCann, M., et al. (2003). "Causes of electrical deaths and injuries among construction workers." Am J Ind Med 43(4): 398-406.

BACKGROUND: Contact with electrical current is the fourth leading cause of deaths of construction workers. This study evaluates electrical deaths and injuries to construction workers. METHODS: Two sources of data were analyzed in detail: (1) 1,019 electrical deaths identified by the Bureau of Labor Statistics, Census of Fatal Occupational Injuries (CFOI) for the years 1992-1998; and (2) 61 electrical injuries identified between November 1, 1990 and December 31, 1998 from a George Washington University Emergency Department injury surveillance database. RESULTS: Contact with "live" electrical wiring, equipment, and light fixtures was the main cause of electrical deaths and injuries among electrical workers, followed by contact with overhead power lines. Among non-electrical workers, contact with overhead power lines was the major cause of death. Other causes included contact with energized metal objects, machinery, power tools, and portable lights. Arc flash or blast caused 31% of electrical injuries among construction workers, but less than 2% of electrical deaths. CONCLUSION: Adoption of a lockout/tagout standard for construction, and training for non-electrical workers in basic electrical safety would reduce the risk of electrical deaths and injuries in construction. Further research is needed on ways to prevent electrical deaths and injuries while working "live".

Memarian, B., et al. (2022). "High-Risk Electrical Tasks & Contributing Work Factors." Professional Safety 67(08): 14-20.

Vergara, X. P., et al. (2015). "Job exposure matrix for electric shock risks with their uncertainties." Int J Environ Res Public Health 12(4): 3889-3902.

We present an update to an electric shock job exposure matrix (JEM) that assigned ordinal electric shocks exposure for 501 occupational titles based on electric shocks and electrocutions from two available data sources and expert judgment. Using formal expert elicitation and starting with data on electric injury, we arrive at a consensus-based JEM. In our new JEM, we quantify exposures by adding three new dimensions: (1) the elicited median proportion; (2) the elicited 25th percentile; and (3) and the elicited 75th percentile of those experiencing occupational electric shocks in a working lifetime. We construct the relative interquartile range (rIQR) based on uncertainty interval and the median. Finally, we describe overall results, highlight examples demonstrating the impact of cut point selection on exposure assignment, and evaluate potential impacts of such selection on epidemiologic studies of the electric work environment. In conclusion, novel methods allowed for consistent exposure estimates that move from qualitative to quantitative measures in this population-based JEM. Overlapping ranges of median exposure in various categories reflect our limited knowledge about this exposure. © 2015 by the authors; licensee MDPI, Basel, Switzerland.

Weisskopf, M. G., et al. (2005). "Prospective study of occupation and amyotrophic lateral sclerosis mortality." Am J Epidemiol 162(12): 1146-1152.

Occupational exposures are suspected of contributing to the risk of amyotrophic lateral sclerosis (ALS), but results of epidemiologic studies have been inconsistent. The authors prospectively assessed the relation between occupation and ALS mortality among more than 1 million participants in the Cancer Prevention Study II of the American Cancer Society. Follow-up from 1989 through 2002 identified 507 ALS deaths among men and 430 among women. Adjusted rate ratios were calculated by using Mantel-Haenszel weights and Cox proportional hazards. Among men, elevated ALS mortality was found for programmers (rate ratio = 4.55, 95% confidence interval: 1.46, 14.2; p = 0.009) and laboratory technicians (rate ratio = 1.96, 95% confidence interval: 1.04, 3.66; p = 0.04). Occupations previously associated with increased risk of ALS for which no increased risk was found included farmers, electricians, and welders, although the numbers of electricians (eight ALS deaths) and welders (two ALS deaths) were small. Among women, only machine assemblers had significantly increased ALS mortality (rate ratio = 2.81, 95% confidence interval: 1.05, 7.53; p = 0.04). Results, which suggest that male programmers and laboratory technicians and female machine assemblers may be at increased risk of death from ALS, should be interpreted cautiously, however, because they are based on small numbers.

Zeng, S., et al. (2010). "Effectiveness of a worker-worn electric-field sensor to detect power-line proximity and electrical-contact." J Safety Res 41(3): 229-239.

PROBLEM: Construction workers suffer the most electrocutions among all industries. Currently, there are no electrical contact warning devices on the market to protect workers. This paper proposes a worker-worn electric-field sensor. As the worker is in proximity to, or in contact with, a live power-circuit, the sensor sets off an audible/visual warning alarm. The sensor also has the potential to wirelessly trip a wireless-capable circuit breaker, and to trigger a wireless transmitter to notify emergency response of an electrical contact. METHODS: An experiment was conducted to measure electric-field variation on simulated human-wrists (10 defrosted hog-legs) in various proximities and in electrical-contact to a simulated power-circuit. The purpose of these tests was to determine the feasibility of developing a worker-worn electric-field detection sensor for use in protecting workers from contact with energized

electrical conductors. RESULTS: This study observed a significant electric-field-magnitude increase as a hog-leg approaches the live-circuit, and the distinct electric-field-magnitude jump as the leg contacts with the live-circuit. The observation indicates that this sensor can be an effective device to warn the workers of electrical hazards. Additionally, the sensor has the potential to wirelessly trip a wireless-capable circuit-breaker and trigger a wireless transmitter (such as a cell phone) to notify an emergency response. The prompt notification prevents the worker from further injury caused by postponed medical-care. IMPACT ON INDUSTRY: Widespread use of this sensor could lower electrocution and electrically related injury rates in the construction industry.

Zhao, D., et al. (2016). "Integrating safety culture into OSH risk mitigation: a pilot study on the electrical safety." Journal of Civil Engineering and Management 22(6): 800-807.

Efforts have been taken for years to minimize the occupational safety and health (OSH) risk, but the injury records remain a constant reason for worldwide concerns. Many firms often implement technology as an administrative hierarchy of control (HOC). However, technologies may also actively influence safe practices at the managerial level for administrative HOC. This research examines electrical safety hazards in the U.S. construction industry as a basis for, studying the feasibility of using technology to integrate safety culture into the administrative level of OSH risk mitigation. The researchers introduce the concept of “habitus”, which suggests one possibility for establishing a safety culture that increases workers’ safety performance and integrates into workers’ safety practices through cutting-edge information technology. A prototype application for OSH training based on mobile virtual reality (MVR) technology is demonstrated to help establish habitus in workers’ daily practices, and ultimately to mitigate OSH risks at the administrative level of construction projects. Results from a preliminary validation test strongly support human behavior influence and safe work knowledge comprehension by the prototyped application. Although this prototype is demonstrated as a pilot study of electrical safety, the application is not limited to this area and is scalable to other OSH risks. © 2016 Vilnius Gediminas Technical University (VGTU) Press.

Zhao, D., et al. (2015). "Control measures of electrical hazards: An analysis of construction industry." Safety science 77: 143-151.

The construction industry has adopted control measures of electrical hazards for decades, however construction workers are still electrocuted in the workplace every year. This problem leads to a need for assessing the quality of control measures. The goal of this study is to assess the control measures of electrical hazards using a perspective of hierarchy of controls (HOC). HOC counts control measures of five levels in descending effectiveness, which are Elimination, Substitution, Engineering, Administration, and Personal protective equipment. This study uses mixed methods of narrative text analysis and statistical analysis in examining 486 NIOSH recommended controls from fatality investigations. Findings reveal that behavioral controls remain prevalent in electrical hazard mitigation even though the knowledge of construction safety and health has increased in the past decades. This study also finds that effectiveness of controls is not statistically different by construction type nor occupation. Proposing a solution, the authors suggest that construction managers strictly stick to HOC rules by giving priority to higher level of controls and highly recommend that the U.S. construction industry leverage its prevention strategy by embracing more technological innovations and incentivizing prevention through design. © 2015 Elsevier Ltd.

Zhao, D., et al. (2014). "Electrical deaths in the US construction: An analysis of fatality investigations." Int J Inj Contr Saf Promot 21(3): 278-288.

Electrocution is among the 'fatal four' in US construction according to the Occupational Safety and Health Administration. Learning from failures is believed to be an effective path to success, with deaths being the most serious system failures. This paper examined the failures in electrical safety by analysing all electrical fatality investigations (N = 132) occurring between 1989 and 2010 from the Fatality Assessment and Control Evaluation programme that is completed by the National Institute of Occupational Safety and Health. Results reveal the features of the electrical fatalities in construction and disclose the most common electrical safety challenges on construction sites. This research also suggests the sociotechnical system breakdowns and the less effectiveness of current safety training programmes may significantly contribute to worker's unsafe behaviours and electrical fatality occurrences. © 2013 © 2013 Taylor & Francis.

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