Decision Tool for Implementation of Recommended Overhead and Underground Distribution Ergonomic Interventions

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Technical Update, May 2017

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ABSTRACT

EPRI has developed a decision tool to help electric utilities prioritize ergonomic interventions they would consider implementing for tasks involving work on overhead distribution lines, manhole/vaults, and direct-buried residential distribution cables. The decision tool is based on EPRI surveys and on-site interviews with personnel at four EPRI-member companies actively using three EPRI ergonomic handbooks (compiled in 2010 into EPRI report 1021128). The tool identifies 19 (of 65 potential) interventions used by at least three, if not all four, of the companies surveyed. Employing a modified version of a prioritization model developed and applied by Duke Energy, the researchers asked what interventions were implemented and why those interventions were chosen. The prioritization model considered an intervention's initial cost, labor savings, and health benefits.

Approximately 50% of the interventions recommended for overhead distribution line work and manhole/vault tasks were implemented among all four participating companies. About 40% of the interventions recommended for direct-buried residential distribution tasks were implemented among three participating companies. General reasons given for implementing interventions included "ergonomics," "reliability," or "safety." One specific reason noted was that a task was very strenuous and was associated with Occupational Safety and Health Administration (OSHA) recordable strains and sprains—one of the top three health and safety priorities for EPRI members.

By reviewing the 19 most implemented ergonomic interventions for distribution tasks described here, utilities can jump start an ergonomics program or compare existing program coverage with up-to-date information provided in this report. The methodology used to develop the simple decision tool described in this report could also be applied to interventions for generation or fleet vehicle maintenance tasks identified in other EPRI handbooks.

Keywords
Ergonomics
Distribution lines
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Manholes
Vaults

EXECUTIVE SUMMARY

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Decision Tool for Implementation of Recommended Overhead and Underground Distribution Ergonomic Interventions

PRIMARY AUDIENCE: Occupational Health and Safety directors and staff

SECONDARY AUDIENCE: Health and Safety/Shared Services senior management

KEY RESEARCH QUESTION

From a total of 65 ergonomic interventions recommended in three *EPRI Ergonomics Handbooks*, which interventions were most commonly used by EPRI members?

RESEARCH OVERVIEW

This research developed a decision tool to help electric utilities prioritize ergonomic interventions they would consider implementing. Through surveys and on-site interviews with personnel at four EPRI-member companies actively using the EPRI handbooks, researchers developed a decision tool that identified 19 (of 65 potential) interventions used by at least three, if not all four, of the companies surveyed. Using a modified version of a prioritization model developed and used by Duke Energy, the researchers asked what interventions were implemented and why those interventions were chosen. The prioritization model considered an intervention's initial cost, labor savings, and health benefits.

KEY FINDINGS

- Approximately 50% of the interventions recommended in the first two handbooks (overhead distribution line work; manhole/vault work) were implemented among the four companies.
- For overhead distribution line work, the most implemented interventions used battery-powered crimpers and cutting tools for wire-connections and for cutting wire #2 AWG or larger.
- For manhole/vault tasks, removing and replacing a manhole cover using a first- or second-class lever was the most implemented intervention.
- For direct-buried residential distribution cable work described in the third handbook, the most implemented interventions used battery powered tools for cutting wire and crimping, as well as a lever-action pulling tool and shotgun stick for removing elbow terminations.
- "Ergonomics," "reliability," or "safety" were the common reasons given for implementing interventions. However, some reasons were more specific. For example, loading wooden crossarms onto trucks and trailers was evaluated because employees reported this task as one of the most strenuous they performed and there were Occupational Safety and Health Administration recordable strains and sprains associated with the task.

WHY THIS MATTERS

EPRI members anecdotally report that reducing injuries from sprains and strains is one of their top three health and safety priorities. Analysis of 19 years of collected injury data in EPRI's Occupational Health and Safety Database shows that sprains and strains represent 30% of overall injuries, 41% of all recordable injuries, and 54% of all injury-related lost work time. Application of interventions recommended in *EPRI Ergonomics Handbooks* may provide electric utilities with enhanced opportunities to reduce such injuries.

HOW TO APPLY RESULTS

Utilities that are exploring implementation of ergonomic interventions described in the *EPRI Ergonomics Handbooks,* or have yet to use the handbooks, may wish to start by reviewing the 19 most implemented interventions described here. Utilities can also use these results to revisit their own ergonomic programs, comparing program coverage with up-to-date information about ergonomic interventions provided in this report.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- *EPRI Occupational Health and Safety Annual Report, 2015: Occupational Health and Safety Trends Among Electric Power Industry Workers, 1999–2014.* EPRI, Palo Alto, CA: 2016. 3002008618.
- *Occupational Health and Safety Database 1995–2013: Injury Surveillance Highlights: Focus in Injury Severity.* EPRI, Palo Alto, CA: 2015. 3002006325.
- *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Design for Substations and Ergonomic Interventions for Overhead, Underground, and Substation Applications.* EPRI, Palo Alto, CA: 2010. 1021128.
- Additional *EPRI Ergonomics Handbooks* for power plant tasks, new fossil-fueled power plant designs, upfitting of utility fleet vehicles, and new fleet vehicle acquisition may be found by searching for “ergonomics” or “ergonomics handbooks” on www.epri.com.

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PROGRAM: Occupational Health and Safety, Program 62

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1 INTRODUCTION

The following three *EPRI Ergonomics Handbooks for the Electric Power Industry* were written by the Marquette University team and distributed by EPRI to its utility members from 2001 to 2008:

1. *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Overhead Distribution Line Workers Interventions*. EPRI, Palo Alto, CA: 2001. 1005199. (32 task interventions)
2. *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Interventions for Manhole, Vault and Conduit Applications*. EPRI, Palo Alto, CA: 2004. 1005430. (16 task interventions)
3. *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Interventions for Direct-Buried Cable Applications*. EPRI, Palo Alto, CA: 2005. 1005574. (17 task interventions)

In these three handbooks,[1] 65 ergonomic interventions were recommended for common tasks performed by overhead and underground distribution workers. These recommendations were written concisely in clear layperson language and accompanied by simple line drawings. Each recommendation—along with an explanation of the task involved and the equipment context—was described in no more than four pages, so that a reader could quickly grasp the context, importance, and benefits of the recommendation. Each four-page description answered the following questions:

1. What are the current work practices associated with the task or the current equipment design?
2. What are the problem(s) or challenge(s) posed by the present work practice or design?
3. What are the recommended ergonomic intervention(s) or equipment design change(s)?
4. What are the benefits of the recommended interventions or design changes?

Each description concluded with a discussion of issues related to present practices and recommended interventions or design changes.

Although some electric utilities (EPRI members and non-members) implemented some or many of the recommendations in the three handbooks, the specific interventions they chose and the total number of interventions they implemented were not known. It appeared that such descriptive information, accompanied by a decision tool, would be useful to utilities that wished to choose additional interventions or try interventions for the first time. This type of information would enable EPRI members to incorporate interventions to enhance worker comfort, reduce muscular-skeletal injuries, and reduce lost time among workers at electric and gas utilities.

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[1] These handbooks are no longer available. They are superseded by *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Design for Substations and Ergonomic Interventions for Overhead, Underground, and Substation Applications.* EPRI, Palo Alto, CA: 2010. 1021128.

2
RESEARCH NEEDS AND OBJECTIVES

EPRI has received anecdotal information about the implementation of specific recommended ergonomic interventions at member and non-member electric utilities, as well as the number of interventions implemented. However, implementation has not been rigorously documented. Hence, the research objectives for this project were the following:

1. Determine the specific recommended ergonomic interventions that have been implemented by U.S. or Canadian electric utilities. Record frequency of implementation, reasons for selecting these interventions (*e.g*., medical and workers compensation cost, cost of interventions, nature of utility's work, request from workers, *etc*.), and the type of each intervention as shown in the EPRI handbooks.
2. Construct a decision tool for U.S. electric utilities to use in prioritizing the implementation of interventions by type and order.
3. Describe the decision tool in a manuscript prepared for submission to an ergonomics journal.

3
METHODOLOGY

One-day site visits to four EPRI-member electric utilities were conducted between September, 2015, and May, 2016. The site-visit utilities were located in four regions of the United States (the West, South, Southeast, and Northeast) and were selected on the basis of three criteria:

- Each company had an active occupational health and safety program and was regarded as a leader in EPRI's Occupational Health and Safety Program (Program 62).
- Each company implemented some of the recommended ergonomic interventions in Handbook 1 (Overhead Distribution tasks), Handbook 2 (Manhole/Vault tasks), and Handbook 3 (Direct-Buried Cable tasks).
- Together, the companies represented geographic diversity across the United States.

To maintain anonymity, the four site-visit utilities are referenced as Utilities A, B, C, and D (not the order of their geographic locations listed above).

Each site visit involved a two- to three-hour meeting with the utility's health and safety personnel for electric distribution operations. Those attending the meeting generally included the safety director, safety staff, supervisory personnel, at least two line workers, and sometimes a purchasing agent. Marquette University principal investigator, Dr. Richard Marklin, led each meeting. Survey forms of recommended interventions from the three handbooks were distributed, and Dr. Marklin showed the meeting participants how to complete the forms, using a few examples.

The survey forms listed all the ergonomic interventions in Handbook 1 (Overhead Distribution tasks), Handbook 2 (Manhole/Vault tasks), and Handbook 3 (Direct-Buried Cable tasks) in a spreadsheet format. Prioritization scores (denoted below by *) are from the Duke Energy prioritization model (Gartland, 2014). As shown in Appendix Tables A-1, A-2, and A-3, columns in the survey forms included:

1. Task number in handbook and task description
2. Recommended ergonomic intervention
3. Initial cost of intervention listed in handbook—with a prioritization score of low (2), medium (1.5), or high (1)*
4. Labor savings of intervention listed in handbook—with a prioritization score of none (0), moderate (1), or substantial (2)*
5. Occupational health benefit of intervention listed in handbook—with a prioritization score of moderate (1) or substantial (2)*
6. Composite prioritization score taking into account items 3, 4, and 5
7. Did the site-visit utility consider the ergonomic intervention (yes/no)?
8. Did the site-visit utility implement the intervention (yes/no)?
9. If yes to question 8, then when, the approximate cost, and why?

10. If no to question 8, then why?

11. Comments

The utility participants were asked to return the completed survey forms to Dr. Marklin within two to three months.

4

DUKE ENERGY PRIORITIZATION MODEL

Each ergonomic intervention for distribution tasks listed in the survey was evaluated for priority of implementation using the Duke Energy prioritization model (Gartland, 2014) developed by James Gartland, Principal Health and Safety Specialist at Duke Energy. To generate a composite prioritization score using the model, prioritization scores (numerical values) were assigned to categories describing the initial cost, labor savings, and occupational health benefit of each ergonomic intervention defined in Handbook 1 (Overhead Distribution tasks), Handbook 2 (Manhole/Vault tasks), and Handbook 3 (Direct-Buried Cable tasks).

Initial Cost of Ergonomic Intervention

The Duke Energy prioritization model assigned the following prioritization scores (numerical values) to initial cost categories defined for each ergonomic intervention in Handbook 1 (Overhead Distribution tasks):

- 1 high initial cost (> $1000)
- 1.5 medium initial cost ($100 to $1000)
- 2 low initial cost (< $100)

For the ergonomic interventions in Handbook 2 (Manhole/Vault tasks) and Handbook 3 (Direct-Buried Cable tasks), the prioritization scores (numerical values) assigned for initial cost categories were:

- 1 high initial cost (> $500)
- 2 low initial cost (< $500)

Note that Handbooks 2 and 3 used only two levels of cost—high (1) and low (2)—rather than the three levels used in Handbook 1. Personnel from the site-visit utility who worked with the Marquette University team that wrote the handbooks mentioned that it was easiest to categorize the initial cost as either less than, or greater than, $500. Therefore, the medium initial cost (1.5) was not reported for the interventions in Handbooks 2 and 3.

Labor Savings of Ergonomic Intervention

The following prioritization scores (numerical values) were assigned to the labor savings categories defined for each intervention in Handbooks 1, 2, and 3:

- 0 no labor savings
- 1 reducing the time to perform a task by up to 15 minutes
- 2 reducing the time to perform a task by more than 15 minutes

Occupational Health Benefit of Ergonomic Intervention

The following prioritization scores (numerical values) were assigned to the occupational health benefit categories defined for each intervention in Handbooks 1, 2, and 3:

- 1 moderate health benefit
- 2 substantial health benefit

Composite Prioritization Score

For each intervention, the prioritization scores for initial cost, labor savings, and occupational health benefit categories were summed and recorded as the composite prioritization score in a column on the survey form. The maximum composite prioritization score for an intervention was 6 (2 + 2 + 2) and the minimum score was 2 (1 + 0 + 1).

Calculating the composite prioritization score as the *sum* of the individual scores was a departure from the Duke Energy prioritization model, which multiplies the sum of the three scores by a coefficient denoting the relative workers compensation cost and injury occurrence associated with a given task, as calculated from information in Duke Energy's databases. This Duke Energy procedure was not used in the present study because the magnitude of workers compensation costs and incidence rates for injuries associated with individual tasks were not recorded by all four site-visit utilities.

5
RESULTS

Survey data analyzed were those related to the overhead and underground distribution tasks described in Handbooks 1, 2, and 3. All of the ergonomic interventions implemented at the four site-visit utilities are shown in detail in Appendices A, B, and C. The initial cost, labor savings, and occupational health benefit are listed for each recommended intervention, along with its Duke Energy composite prioritization score. The number of site-visit utilities implementing each intervention is shown, along with the year of implementation, the cost of the intervention, and the reasons for implementation. Some site-visit utilities did not provide data for all cells; cells without data are shown as ND (No Data).

As shown in Tables 5-1, 5-2, and 5-3, the ergonomic interventions using battery-powered tools for crimping connectors and cutting cable were implemented by all four site-visit utilities for Handbook 1 (Overhead Distribution tasks) and by three site-visit utilities for Handbook 2 (Manhole/Vault tasks) and Handbook 3 (Direct-Buried Cable tasks); the cost of the battery-powered tools ranged from \$1500 to \$5000 each. These interventions were implemented as early as 2000 by one utility and will be rolled out in 2017 by another utility.

Use of a lever tool for the removing and replacing a manhole cover described in Handbook 2 (Manhole/Vault tasks) was either implemented by, or under investigation by, four utilities; the cost of the lever tool was \$200, according to one utility.

Three of the four site-visit utilities implemented eight ergonomic interventions from Handbook 1 (Overhead Distribution tasks), five interventions from Handbook 2 (Manhole/Vault tasks), and three interventions from Handbook 3 (Direct-Buried Cable tasks).

Table 5-1
Ergonomic interventions from Handbook 1 (Overhead Distribution tasks) implemented by at least three of the four site-visit utilities

	Ergonomic Interventions Implemented by Three Utilities		**Ergonomic Interventions Implemented by Four Utilities**	
	Task	**Recommended Ergonomic Intervention (Cost)**	**Task**	**Recommended Ergonomic Intervention (Cost)**
Handbook 1 (Overhead Distribution Tasks)	3.7 Tightening or Loosening Nuts on Long Bolts	Deep well socket to power drill to tighten or loosen nuts on long bolts ($150)	3.26 Wire Connection Methods	Battery-powered crimping tool ($1500, $5000)
	3.9 Cutting Wire with a Linemen's Pliers	Use pliers with pivot point close to the cutting blade ($50)	3.27 Cutting Wire #2 AWG or Larger	Battery-powered cutting tool ($1500, $5000)
	3.11 Connecting Ground Wire to Ground Rod	Screw-on connection or powder-activated wedge connector ($1)		
	3.12 Installing a Guy Wire Grip	Automatic guy grip to anchor head or pole attachment ($2.40)		
	3.17 Opening and Closing a Fuse Cutout with a Telescoping Live Line Tool	Paint large ring of fuse cutout with highly visible color (> $100, $500)		
	3.21 Digging Pole Holes on Private Property	Dig holes with water pressure with vacuum truck (mud sucker) ($64,000)		
	3.22 Tamping a Backfilled Hole	Chemical mixture into hole for strong support around base; use hydraulic tamper ($10/ft^3, $28,000 for tool)		
	3.30 Installing Anchors on Private Property	Portable auguring system to install a screw-in style anchor ($2100 for tool)		

Table 5-2
Ergonomic interventions from Handbook 2 (Manhole/Vault tasks) implemented by at least three of the four site-visit utilities

	Ergonomic Interventions Implemented by Three Utilities		Ergonomic Interventions Implemented by Four Utilities (or Under Investigation)	
	Task	**Recommended Ergonomic Intervention (Cost)**	**Task**	**Recommended Ergonomic Intervention (Cost)**
Handbook 2 (Manhole/Vault Tasks)	3.2 Chamfering Plastic Insulation of Cables	Cylindrical or ring-type chamfering tool over conductor ($200)	3.10 Removing and Replacing a Manhole Cover	First or second class lever ($200)
	3.3 Tightening/ Loosening Connector Between 600 Amp Primary Elbows	Double-toothed spanner tool ($200)		
	3.7 Manual Bending (or Training) of Cable	Cable with benders or trainers ($500)		
	3.14 Cutting Cable	Battery -powered cutter; AC pump with remote hydraulic cutting head ($5000)		
	3.15 Crimping Sleeve Connections and Lugs	Battery-powered press; AC pump with remote hydraulic press ($5000)		

Table 5-3
Ergonomic interventions from Handbook 3 (Direct-Buried Cable tasks) implemented by at least three of the four site-visit utilities

	Ergonomic Interventions Implemented by Three Utilities		Ergonomic Intervention Implemented by Four Utilities	
	Task	**Recommended Ergonomic Intervention (Cost)**	**Task**	**Recommended Ergonomic Intervention (Cost)**
Handbook 3 (Direct-Buried Cable Tasks)	3.7 Removing Elbow Terminations	Lever-action pulling tool and shotgun stick ($180)	None	None
	3.16 Cutting Cable	Battery-powered cutting tool ($3700)		
	3.17 Crimping Sleeves and Lugs	Battery-powered press ($1800, $3400)		

The median number of interventions implemented by the four site-visit utilities was 15.5 for tasks in Handbook 1 (Overhead Distribution tasks), 9 for tasks in Handbook 2 (Manhole/Vault tasks), and 7 for tasks Handbook 3 (Direct-Buried Cable tasks), as indicated in Table 5-4. The median number of implemented interventions was 48.4, 56.3, and 41.2% of all the tasks in the respective three handbooks.

Table 5-4
Number and percentage of ergonomic interventions implemented by site-visit utilities for Handbooks 1, 2, and 3

	Handbook 1 (Overhead Distribution Tasks)	**Handbook 2 (Manhole/Vault Tasks)**	**Handbook 3 (Direct-Buried Cable Tasks)**
Utility A	25	10	10
Utility B	4	2	2
Utility C	16	8	10
Utility D	15	11	4
Average	**15**	**7.75**	**6.5**
Median	**15.5**	**9**	**7**
Range	**[4, 25]**	**[2, 11]**	**[2, 10]**
Number of interventions in Handbook	32	16	17
Average as % of number of interventions	46.9%	48.4%	38.2%
Median as % of number of interventions	48.4%	56.3%	41.2%

Each intervention implemented by a utility was weighted according to its Duke Energy composite prioritization score; then the interventions were summed for each handbook, as shown in Table 5-5. (As discussed in Section 4, the maximum and minimum scores per intervention were 6 and 2, respectively.) The maximum weighted prioritization score of all tasks was 140 points for Handbook 1 (Overhead Distribution tasks), 70 points for Handbook 2 (Manhole/Vault tasks), and 84 points for Handbook 3 (Direct-Buried Cable tasks). The weighted score of the median number of implemented interventions was 65.75, 33.5, and 31.5 points for the respective three handbooks. These weighted sums were 47.9, 56.4, and 39.3% of the total weighted score of all tasks in each handbook.

Table 5-5
Sum of weighted composite prioritization scores of ergonomic interventions implemented by each utility

	Handbook 1 (Overhead Distribution Tasks)	**Handbook 2 (Manhole/Vault Tasks)**	**Handbook 3 (Direct-Buried Cable Tasks)**
	Sum of Weighted Composite Prioritization Scores*		
Utility A	111	43	48
Utility B	18	8	10
Utility C	70.5	36	50
Utility D	63.5	47	18
Average	**65.75**	**33.5**	**31.5**
Median	**67**	**39.5**	**33**
Range	**[18, 111]**	**[8, 47]**	**[10, 50]**
Max weighted score of all interventions	140	70	84
Average as % of max weighted score	47.0%	47.9%	37.5%
Median as % of max weighted score	47.9%	56.4%	39.3%

*Each implemented task was multiplied by its Duke Energy composite prioritization score, and the sum of the weighted scores is presented for each handbook.

The Duke Energy composite prioritization score per task for all interventions in each handbook was 4.375, 4.375, and 4.94, as indicated in Table 5-6. The scores per average and median number of implemented interventions were generally similar to the scores for all tasks, although the scores for the average and median number of implemented interventions in Handbook 3 (Direct-Buried Cable tasks) were lower (4.84 and 4.71, respectively) than the 4.94 average score for all tasks.

Table 5-6
Duke Energy composite prioritization score per task for all interventions and for implemented interventions

	Handbook 1 (Overhead Distribution Tasks)	**Handbook 2 (Manhole/Vault Tasks)**	**Handbook 3 (Direct-Buried Cable Tasks)**
Score per task for *all* interventions in handbook	**4.38** (140/32)[1]	**4.38** (70/16)	**4.94** (84/17)
Score per *average* number of implemented interventions	**4.38** (65.75/15)[2]	**4.32** (33.5/7.75)	**4.84** (31.5/6.5)
Score per *median* number of implemented interventions	**4.32** (67/15.5)[3]	**4.39** (39.5/9)	**4.71** (33/7)

[1]Data enclosed in the parentheses in this row show how the score per task for *all* interventions was calculated. In this cell, the maximum weighted score of all interventions (140, from Table 5-5) was divided by the number of interventions (32, from Table 5-4).

[2]Data enclosed in the parentheses in this row show how the score per *average* number of implemented interventions was calculated. In this cell, the average weighted score of interventions implemented by utilities (65.75, from Table 5-5) was divided by the average number of implemented interventions (15, from Table 5-4).

[3]Data enclosed in the parentheses in this row show how the score per *median* number of implemented interventions was calculated. In this cell, the median weighted score of interventions implemented by utilities (67, from Table 5-5) was divided by the median number of implemented interventions (15.5, from Table 5-4).

The right-hand column (Reasons for Implementing Intervention) in Appendix Tables A-1, B-1, and C-1 offers useful insights into why utilities implemented a recommended intervention. Many of the reasons given for implementing interventions were general, such as "ergonomics," "reliability," or "safety," but some reasons were more specific. For example, Utility B implemented the recommended intervention for Task 3.16 in Table A-1 (Loading Wooden Crossarms onto Trucks and Trailers from Handbook 1) because employees reported this task as one of the most strenuous they performed and there were Occupational Safety and Health Administration recordable strains and sprains associated with the task.

6 DISCUSSION

The median number of interventions implemented by the four site-visit utilities was approximately 50% of all the tasks in Handbook 1 (Overhead Distribution tasks), 50% of all the tasks in Handbook 2 (Manhole/Vault tasks) and 40% of all the tasks in Handbook 3 (Direct-Buried Cable tasks) (Tables 5-4 and 5-5). These percentages demonstrate that the four EPRI-member site-visit utilities took the handbook recommendations seriously and the ergonomic interventions had broad appeal to utilities in different regions of the United States.

The ergonomic interventions most commonly implemented were those involving the use of battery-powered tools for cutting cable and making crimp connections; their high rate of implementation agreed with anecdotal reports from utilities placing a high priority on these interventions. While the cost of the battery-powered tools is high (at least $1500 per tool, as reported by the utilities), the payback period for these tools is less than 16 months (Seeley and Marklin, 2003; Seeley *et al*., 2008). Analysis of the payback period was funded in part by EPRI, and EPRI supported laboratory evaluations of the battery-powered tools (Stone *et al*., 2006, 2011). Dissemination of these findings through EPRI meetings and publications, along with public domain articles, probably contributed to the high rate of implementation of interventions described in these studies.

Use of a lever tool for removing and replacing a manhole cover was the most commonly implemented intervention (4 utilities) in Handbook 2 (Manhole/Vault tasks). Possible reasons for this intervention's high rate of implementation include the high risk of injury associated with task performance, the commercial availability of several lever tools, and the low cost ($200) of the lever tools.

When the Duke Energy prioritization model was applied to weight each intervention according to initial cost, labor savings, and occupational health benefit, the weighted scores per implemented intervention in the three handbooks were very close to the average and median weighted scores of *all* interventions (Table 5-6). For example, the weighted score of all interventions in Handbook 1 (Overhead Distribution tasks) was 4.38, while the weighted scores per average and median number of implemented interventions were 4.38 and 4.32, respectively. These results show that the utilities implemented interventions with a range of weighted scores—low (2 to 3), medium (3 to 5), and high (5 to 6)—and did not implement a large number of interventions with extreme scores. This finding suggests that the interventions in the handbooks had relatively broad appeal to utilities considering adoption of ergonomic interventions.

7
DECISION TOOL

Only four utilities participated in this study and some of them did not complete all of the survey questions (*e.g.,* cells with no data [ND], as shown in Appendix Tables A-1, B-1, and C-1). Thus, the best decision tool for choosing ergonomic interventions would be one based on interventions that were implemented by three or four participating utilities.

As shown in Table 7-1, the first-tier interventions that utilities should consider from Handbook 1 (Overhead Distribution tasks) and Handbook 2 (Manhole/Vault tasks) are those implemented by all four utilities. Second-tier interventions are those implemented by three of the four utilities surveyed. For Handbook 3 (Direct-Buried Cable tasks), the first-tier interventions are those implemented by three utilities; there were no interventions implemented by all four utilities.

The recommended ergonomic interventions for tasks in Handbooks 1, 2, and 3 were written to address the common work practices of electric utilities in the United States and Canada. Due to variations across regions, climates, or equipment, some of the recommended interventions may not be applicable to the work practices of all utilities.

Table 7-1
Decision tool matrix for implementation of ergonomic interventions from EPRI handbooks

		Task	Intervention	Task	Intervention
Handbook 1 (Overhead Distribution Tasks)	**First-Tier Interventions***	3.26 Wire Connection Methods	Battery-powered crimping tool ($1500, $5000)	3.27 Cutting Wire #2 AWG or Larger	Battery-powered cutting tool ($1500, $5000)
	Second-Tier Interventions	3.7 Tightening or Loosening Nuts on Long Bolts	Deep well socket to power drill to tighten or loosen nuts on long bolts ($150)	3.9 Cutting Wire with a Linemen's Pliers	Use pliers with pivot point close to the cutting blade ($50)
		3.11 Connecting Ground Wire to Ground Rod	Screw-on connection or powder-activated wedge connector ($1)	3.12 Installing a Guy Wire Grip	Automatic guy grip to anchor head or pole attachment ($2.40)
		3.17 Opening and Closing a Fuse Cutout with a Telescoping Live Line Tool	Paint large ring of fuse cutout with highly visible color (> $100, $500)	3.21 Digging Pole Holes on Private Property	Dig holes with water pressure with vacuum truck (mud sucker) ($64,000)
		3.22 Tamping a Backfilled Hole	Chemical mixture into hole; use hydraulic tamper ($10/ft3, $28,000 for tool)	3.30 Installing Anchors on Private Property	Portable auguring system to install a screw-in style anchor ($2100 for tool)
Handbook 2 (Manhole/Vault Tasks)	**First-Tier Intervention**	3.10 Removing and Replacing a Manhole Cover	First or second class lever ($200)		
	Second-Tier Interventions	3.14 Cutting Cable	Battery -powered cutter; AC pump with remote hydraulic cutting head ($5000)	3.15 Crimping Sleeve Connections and Lugs	Battery-powered press; AC pump with remote hydraulic press ($5000)
		3.2 Chamfering Plastic Insulation of Cables	Cylindrical or ring-type chamfering tool over conductor ($200)	3.3 Tightening/ Loosening Connector Between 600 Amp Primary Elbows	Double-toothed spanner tool ($200)
		3.7 Manual Bending (or Training) of Cable	Cable with benders or trainers ($500)		

Table 7-1 (continued)
Decision tool matrix for implementation of ergonomic interventions from EPRI handbooks

		Task	**Intervention**	**Task**	**Intervention**
Handbook 3 (Direct-Buried Cable Tasks)	**First-Tier Interventions**	3.16 Cutting Cable	Battery-powered cutting tool ($3700)	3.17 Crimping Sleeves and Lugs	Battery-powered press ($1800, $3400)
		3.7 Removing Elbow Terminations	Lever-action pulling tool and shotgun stick ($180)		

*First-tier interventions should be considered first for implementation; second-tier interventions are for subsequent consideration. Interventions within each tier are not listed with respect to priority of implementation.

8 RECOMMENDATIONS

The results of this initial effort to develop a decision tool suggest that more complex decision trees are not needed to provide guidance to utilities interested in using interventions recommended in the *EPRI Ergonomics Handbooks.* Moreover, the results suggest that the methodology used here could be applied to the three power generation handbooks:[2]

- *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Interventions for Electrical Workers in Fossil-Fueled Power Plants*. EPRI, Palo Alto, CA: 2008. 1014042. (16 task interventions)
- *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Interventions for Plant Operators and Mechanics in Fossil-Fueled Power Plants*. EPRI, Palo Alto, CA: 2008. 1015631. (16 task interventions)
- *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomics Design Handbook for Fossil-Fueled Electric Generating Stations*. EPRI, Palo Alto, CA: 2008. 1014942. (> 30 design equipment recommendations)

The methodology could also be applied to the two fleet vehicle handbooks:

- *EPRI Ergonomics Handbook for the Electric Power Industry: Process Guidelines for Acquisition and Ergonomics Guidelines for Vehicle Maintenance*. EPRI, Palo Alto, CA: 2011. 1021836. (> 30 guidelines)
- *EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Design and Specifications of Turnkey and Upfitted Fleet Vehicles*. EPRI, Palo Alto, CA: 2012. 1021835. (> 50 design equipment recommendations)

It would also be useful to conduct a workshop on lessons learned from implementation of interventions described in the *EPRI Ergonomics Handbooks*. The target audience would be occupational health and safety staff from EPRI-member companies in the utility sector and companies not previously involved in development or implementation of handbook content.

During this project, some respondents provided brief commentary on the benefits they expected to receive from implementing ergonomic interventions. While this anecdotal information may be helpful to new users, documenting the qualitative and quantitative benefits associated with interventions would further guide utility health and safety staff who are looking for the "low-hanging fruit" among ergonomic interventions they may choose to implement.

[2]The original design of the present study included generation tasks described in the first two handbooks listed here. However, two of the four site-visit utilities did not have generating stations and were unable to provide feedback on the tasks in these handbooks. Thus, generation tasks were not included in the Duke Energy prioritization analysis.

9 REFERENCES

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EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Interventions for Direct-Buried Cable Applications. EPRI, Palo Alto, CA: 2005. 1005574. (17 task interventions)

EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Interventions for Electrical Workers in Fossil-Fueled Power Plants. EPRI, Palo Alto, CA: 2008. 1014042 (16 task interventions)

EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomics Design Handbook for Fossil-Fueled Electric Generating Stations. EPRI, Palo Alto, CA: 2008. 1014942. (> 30 design equipment recommendations)

EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Interventions for Plant Operators and Mechanics in Fossil-Fueled Power Plants. EPRI, Palo Alto, CA: 2008. 1015631. (16 task interventions)

EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Design for Substations and Ergonomic Interventions for Overhead, Underground, and Substation Applications. EPRI, Palo Alto, CA: 2010. 1021128. (> 60 task interventions)

EPRI Ergonomics Handbook for the Electric Power Industry: Process Guidelines for Acquisition and Ergonomics Guidelines for Vehicle Maintenance. EPRI, Palo Alto, CA: 2011. 1021836. (> 30 guidelines)

EPRI Ergonomics Handbook for the Electric Power Industry: Ergonomic Design and Specifications of Turnkey and Upfitted Fleet Vehicles. EPRI, Palo Alto, CA: 2012. 1021835. (> 50 design equipment recommendations)

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A

SURVEY DATA FROM HANDBOOK 1 (OVERHEAD DISTRIBUTION TASKS)

Table A-1
Survey Data From Handbook 1 (Overhead Distribution Tasks)

Handbook 1 (Overhead Distribution Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.1	Installing a Pin Insulator	Ratchet handle that fits around neck of pin insulator	Low (< $100)	2.0	None to Moderate	0.5	Moderate	1.0	3.5	**0**			
3.2	Installing a 35kV Insulator	Polymeric insulators for heavier ceramic insulators	Low (< $100)	2.0	None to Moderate	0.5	Moderate	1.0	3.5	**II**	A: 2005 D: ND	A: ND D: ND	A: reliability, ergonomics D: ND
3.3	Installing a Tie Wire on a Spool Insulator	Straight preformed tie placed under spool insulator	Low (< $100)	2.0	None to Moderate	0.5	Moderate	1.0	3.5	**II**	C: 1980 D: ND	C: $1.57 D: ND	C: more uniform and secure connection D: ND
3.4	Die Location of Manual Compression Press	Utilize inner die of manual compression tool	Low (< $100)	2.0	None	0.0	Substantial	2.0	4.0	**II**	A: 2016 C: 1980	A: ND C: $244	A: ergonomics C: uniform crimp with less stress to worker and less exposure in energized situations

Table A-1 (continued)
Survey Data From Handbook 1 (Overhead Distribution Tasks)

Handbook 1 (Overhead Distribution Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	**Task Description**	**Ergonomic Intervention**	**Category**	**Prioritization Score**	**Category**	**Prioritization Score**	**Category**	**Prioritization Score**					
3.5	Connecting Service Wires to a Secondary Main	Secondary set screw connector block attached to the wires	Low (< $100)	2.0	Substantial	2.0	Moderate	1.0	5.0	**0**			
3.6	Installing an Open Wire Spacer	Polyethylene tubes over the conductors	Low (< $100)	2.0	Moderate	1.0	Substantial	2.0	5.0	**I**	D: ND	D: ND	D: ND
3.7	Tightening or Loosening Nuts on Long Bolts	Deep well socket to power drill to tighten or loosen nuts on long bolts.	Low (< $100)	2.0	Moderate	1.0	Moderate	1.0	4.0	**III**	A: 2005 C: 1980 D: 2011	A: ND C: $149 D: ND	A: ergonomics C: labor savings D: ND
3.8	Securing a Stringing Pulley to a Crossarm	Socket fits over wing nut to a hydraulic or electric drill to tighten or loosen wing nuts.	Low (< $100)	2.0	Moderate	1.0	Moderate	1.0	4.0	**0**			
3.9	Cutting Wire with a Linemen's Pliers	Use pliers with pivot point close to the cutting blade.	Low (< $100)	2.0	None to Moderate	0.5	Substantial	2.0	4.5	**III**	A: 2001 C: 1980 D: 2005	A: ND C: $48 D: ND	A: ergonomics C: simple to use D: ND

Table A-1 (continued)
Survey Data From Handbook 1 (Overhead Distribution Tasks)

Handbook 1 (Overhead Distribution Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.10	Driving Ground Rods	Electric hammer drill drives ground rod; use two ground rods with a coupler	Low (< $100)	2.0	Moderate	1.0	Substantial	2.0	5.0	**I**	A: 2001	A: ND	A: safety
3.11	Connecting Ground Wire to Ground Rod	Screw-on connection or powder-activated wedge connector	Low (< $100)	2.0	Substantial	2.0	Moderate	1.0	5.0	**III**	A: 1980 C: 1980 D: ND	A: ND C: $1 D: ND	A: safety C: simple to use and better electrical connection D: ND
3.12	Installing a Guy Wire Grip	Automatic guy grip to anchor head or pole attachment	Low (< $100)	2.0	Moderate	1.0	Substantial	2.0	5.0	**III**	A: 1980 C: 1985	A: ND C: $2.40	A: safety C: saves times and effort
3.13	Inspecting Line Hoses	Clamp line hose spreader to vise	Low (< $100)	2.0	Moderate	1.0	Substantial	2.0	5.0	**0**			
3.14	Operating Vibrating Power Tools	Anti-vibration gloves that meet ISO standard 10919;1996	Low (< $100)	2.0	None	0.0	Moderate	1.0	3.0	**I**	D: 2006	D: ND	D: ND

Table A-1 (continued)
Survey Data From Handbook 1 (Overhead Distribution Tasks)

Handbook 1 (Overhead Distribution Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.15	Storage and Handling of Prepackaged Hand Coils of Wire	Maneuver hand coils with mechanical lifting aid	Low (< $100)	2.0	Moderate to Substantial	1.5	Substantial	2.0	5.5	**I**	A: 2000	A: ND	A: ergonomics
3.16	Loading Wooden Crossarms onto Trucks or Trailers	Lift crossarms using mechanical lifting aid; lighter cross-arm material.	Low (< $100)	2.0	Substantial	2.0	Substantial	2.0	6.0	**II**	A: 2000 B: 2011	A: ND B: $40	A: ergonomics B: problems with strains/sprains from lifting crossarms by hand. Employees reported this as one of the most strenuous tasks.
3.17	Opening and Closing a Fuse Cutout with a Telescoping Live Line Tool	Paint large ring of fuse cutout with highly visible color	Low (< $100)	2.0	Moderate	1.0	Substantial	2.0	5.0	**III**	A: 2015 B: 2015 C: 1981	A: ND B: > $100 C: $499	A: ergonomics B: workers could not see ring at night. Fluorescent paint helps in visibility C: reduces pole climbing (large ring not painted)
3.18	Installing Jumpers with Live Line Tools	Attach hot line clamp onto conductor with live line tool and screw tight	Low (< $100)	2.0	Moderate to Substantial	1.5	Substantial	2.0	5.5	**II**	A: 1980 C: 1980	A: ND C: ND	A: safety C: increases worker safety with distance from connector

Table A-1 (continued)
Survey Data From Handbook 1 (Overhead Distribution Tasks)

Handbook 1 (Overhead Distribution Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.19	Dead-Ending Wire	Automatic dead-end shoe in place of side-entry dead-end shoe	Low (< $100)	2.0	Moderate	1.0	Substantial	2.0	5.0	**II**	A: 2017 C: 1980	A: ND C: $1	A: ergonomics C: ease of installation and more uniform securement
3.20	Installing a Portable Roadway System	Composite fiberglass mats with special texture that minimize suction with wet or muddy ground.	Medium ($100 → $1,000)	1.5	Moderate to Substantial	1.5	Substantial	2.0	5.0	**II**	A: 2010 C: 1998	A: ND C: $155	A: savings on plywood - use composite mats C: reduces effort to access muddy locations
3.21	Digging Pole Holes on Private Property	Dig holes with water pressure with vacuum truck (mud sucker)	Medium ($100 → $1,000)	1.5	Substantial	2.0	Substantial	2.0	5.5	**III**	A: 2005 C: 1995 D: ND	A: ND C: $64,000 D: ND	A: ergonomics, efficiency, safety C: ability to excavate around sensitive/critical UG utilities (fiber optics) D: ND
3.22	Tamping a Backfilled Hole	Chemical mixture into hole for strong support around base; use hydraulic tamper	Medium ($100 → $1,000)	1.5	Moderate	1.0	Substantial	2.0	4.5	**III**	A: 2005 C: 1998 D: ND	A: ND C: foam: $31 per 3 ft3; $2800 tamper D: ND	A: ergonomics, safety C: more stable hole backfill in clay and mud; pole stability D: ND

Table A-1 (continued)
Survey Data From Handbook 1 (Overhead Distribution Tasks)

Handbook 1 (Overhead Distribution Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.23	Leveling Ladders	Adjustable levelers on ladder legs	Medium ($100 → $1,000)	1.5	Moderate	1.0	Substantial	2.0	4.5	**II**	A: 2014 D: ND	A: ND D: ND	A: safety, ergonomics D: ND
3.24	Installing Dead-End Crossarms	Fiberglass dead-end crossarm to pole; support crossarm by mechanical aids.	Medium ($100 → $1,000)	1.5	Moderate to Substantial	1.5	Substantial	2.0	5.0	**I**	A: 2013	A: ND	A: ergonomics
3.25	Removing Pole Steps	Twist socket over pole step until hook on end of pole step laches into end of socket;	Medium ($100 → $1,000)	1.5	Moderate to Substantial	1.5	Moderate	1.0	4.0	**I**	A: 2005	A: ND	A:ergonomics
3.26	Wire Connection Methods	Battery-powered crimping tool	High (> $1,000)	1.0	None to Moderate	0.5	Substantial	2.0	3.5	**IIII**	A: 2005 B: 2008 C: 2006 D: ND	A: ND B: $1500 C: $5000 D: ND	A: ergonomics, safety; B: high incidence of ergonomic injuries and employee complaints of shoulder pain. Professional consultant advised that 90% of population could not safely use these manual tools C: saves employee wear and tear; prevents injuries over long term D: ND

Table A-1 (continued)
Survey Data From Handbook 1 (Overhead Distribution Tasks)

Handbook 1 (Overhead Distribution Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.27	Cutting Wire #2 AWG or Larger	Battery-powered cutting tool	High (> $1,000)	1.0	None to Moderate	0.5	Substantial	2.0	3.5	**IIII**	A: 2017 B: 2008 C: 2000 D: ND	A: ND B: $1500 C: $5000 D: ND	A: ergonomics, safety B: high incidence of ergonomic injuries and employee complaints of shoulder pain. Professional consultant advised that 90% of population could not safely use these manual tools. C: saves employee wear and tear; prevents injuries over long term D: ND
3.28	Bucket Design	Toe spaces outside wall; padding inside of bucket for cushioning	High (> $1,000)	1.0	None	0.0	Moderate	1.0	2.0	**I**	A: ND	A: ND	A: ergonomics, safety
3.29	Location of Controls on a Digger Derrick	Turret-mounted operator seat to boom	High (> $1,000)	1.0	None	0.0	Moderate	1.0	2.0	**II**	A: 1985 C: 1975	A: ND C: ND	A: ergonomics, safety C: seated positioning of operator
3.30	Installing Anchors on Private Property	Portable auguring system to install a screw-in style anchor	High (> $1,000)	1.0	Substantial	2.0	Substantial	2.0	5.0	**III**	A: 2010 C: 1972 D: ND	A: ND C: $2100 D: ND	A: ergonomics, safety C: more secure anchor point D: ND

Table A-1 (continued)
Survey Data From Handbook 1 (Overhead Distribution Tasks)

Handbook 1 (Overhead Distribution Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.31	Driving Utility Trucks Across Ditches or Other Obstacles	portable aluminum bridges; lift using jib on a bucket or boom on truck	High (> $1,000)	1.0	Substantial	2.0	Substantial	2.0	5.0	**I**	A: 2005	A: ND	A: safety, ergonomics
3.32	Loading and Unloading Extension Ladders on a Truck	Lever arm to swing ladder rack from top of truck to side	High (> $1,000)	1.0	None to Moderate	0.5	Substantial	2.0	3.5	**II**	A: 2010 D: ND	A: ND D: ND	A: ergonomics, safety D: ND

*Composite prioritization score = IC + LS + OH
A, B, C, and D = site-visit utilities
ND = no data reported in survey

B

SURVEY DATA FROM HANDBOOK 2 (MANHOLE/VAULT TASKS)

Table B-1
Survey Data From Handbook 2 (Manhole/Vault Tasks)

Handbook 2 (Manhole/Vault Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.1	Connecting Conduit	Dead blow hammer	Low (< $500)	2.0	None	0.0	Substantial	2.0	4.0	**0**			
3.2	Chamfering Plastic Insulation of Cables	Cylindrical or ring-type chamfering tool over conductor	Low (< $500)	2.0	None	0.0	Moderate	1.0	3.0	**III**	A: ND C: 2000 D: ND	A: ND C: $200 D: ND	A: ergonomics C: reduces knife use D: ND
3.3	Tightening/ Loosening Connector Between 600 Amp Primary Elbows	Double-toothed spanner tool	Low (< $500)	2.0	Substantial	2.0	Moderate	1.0	5.0	**III**	A: ND C: 1990 D: ND	A: ND C: $200 D: ND	A: ergonomics C: ensures proper torque to equipment D: ND
3.4	Cutting Conduit	Battery-powered cutting tool; electric saw	Low (< $500)	2.0	Moderate	1.0	Substantial	2.0	5.0	**II**	A: ND D: ND	A: ND D: ND	A: ergonomics

Table B-1 (continued)
Survey Data From Handbook 2 (Manhole/Vault Tasks)

Handbook 2 (Manhole/Vault Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.5	Forming the Ends of a Lead Sleeve	Mallet with board-mounted rollers	Low (< $500)	2.0	Substantial	2.0	Substantial	2.0	6.0	**0**			
3.6	Pigtailing Concentric Neutral Wires on a Primary Cable	Crank method or a drill with an eyebolt	Low (< $500)	2.0	Moderate	1.0	Moderate	1.0	4.0	**I**	A: ND	A: ND	A: ergonomics
3.7	Manual Bending (or Training) of Cable	Cable with benders or trainers	Low (< $500)	2.0	None	0.0	Substantial	2.0	4.0	**III**	A: ND C: 1981 D: ND	A: ND C: $500 D: ND	A: ergonomics C: reduces stress on body D: ND
3.8	Installing a Portable Roadway System	Composite, fiberglass or plastic mats	Low (< $500)	2.0	None	0.0	Substantial	2.0	4.0	**II**	A: ND B: 2005	A: ND B: $800	A: ergonomics, safety B: Numerous complaints from workers pulling plywood from wet, mucky ground. Composite mats much easier to handle and remove. They do not stick.
3.9	Entering and Exiting a Manhole	Ladder extension into manhole chimney	Low (< $500)	2.0	None	0.0	Substantial	2.0	4.0	**II**	A: ND D: ND	A: ND D: ND	A: ergonomics D: fixed ladders removed from manholes

Table B-1 (continued)
Survey Data From Handbook 2 (Manhole/Vault Tasks)

Handbook 2 (Manhole/Vault Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.10	Removing and Replacing a Manhole Cover	Second class lever	Low (< $500)	2.0	None	0.0	Substantial	2.0	4.0	**IIII**	A: under investigation B: 2014 (trolley lifter) C: 1990 D: under investigation	A: ND B: ND C: $200 D: ND	A: ergonomics B: Injury incident from dropped grate caused broken finger and an electrical outage. Employee complaints about the effort required to lift manholes/grates. C: has wide variety of options for different lids D: ND
3.11	Pulling Cable Through Conduit in Manholes or Vaults	Cable reel carrier	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**II**	C: 2010 D: ND	C: $500 D: ND	C: cable truck provides straight line into duct D: trucks pull cable through ducts
3.12	Standing in a Manhole	Manhole height > 78 in.	High (> $500)	1.0	None	0.0	Moderate	1.0	2.0	**I**	D: ND	D: ND	D: ergonomics is design criterion for new manholes
3.13	Moving Heavy Electrical Equipment in Vaults	Rollers and steering bars.	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**II**	C: 2012 D: ND	C: $4000 D: ND	C: reduces stress from moving heavy objects D: transformers moved by heavy equipment

Table B-1 (continued)
Survey Data From Handbook 2 (Manhole/Vault Tasks)

Handbook 2 (Manhole/Vault Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.14	Cutting Cable	Battery - powered cutter; AC pump with remote hydraulic cutting head	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**III**	A: ND C: 2000 D: ND	A: ND C: $5000 D: ND	A: ergonomics, safety C: saves time and reduces wear and tear on body D: ND
3.15	Crimping Sleeve Connections and Lugs	Battery-powered press; AC pump with remote hydraulic press.	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**III**	A: ND C: 2000 D: ND	A: ND C: $5000 D: ND	A: ergonomics, safety C: saves time and reduces wear and tear on body D: ND
3.16	Doweling Concrete	Self-feeding pneumatic pavement drill mounted on movable carriage	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**0**			

*Composite prioritization score = IC + LS + OH
A, B, C, and D = site-visit utilities
ND = no data reported in survey

C

SURVEY DATA FROM HANDBOOK 3 (DIRECT-BURIED CABLE TASKS)

Table C-1
Survey Data From Handbook 3 (Direct-Buried Cable Tasks)

Handbook 3 (Direct-Buried Cable Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.1	Working Height for Installing Residential Service	Work at elbow height	Low (< $500)	2.0	Moderate	1.0	Moderate	1.0	4.0	**I**	D: ND	D: ND	D: step ladders selected for type of job
3.2	Installing & Energizing Secondary Service in Residential Areas	Sit or kneel with trunk upright on metal box or pedestal	Low (< $500)	2.0	Substantial	2.0	Substantial	2.0	6.0	**I**	A: ND	A: ND	A: ergonomics
3.3	Manual Digging and Shoveling	Shovel with holes in the blade for digging sticky clay	Low (< $500)	2.0	Moderate	1.0	Moderate	1.0	4.0	**I**	B: 2012	B: > $100	B: Distribution group saw information in handbook on perforated shovels. Incidents of back and shoulder injuries from shoveling, especially in wet soil and clay.

Table C-1 (continued)
Survey Data From Handbook 3 (Direct-Buried Cable Tasks)

Handbook 3 (Direct-Buried Cable Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.4	Backfilling Excavations	Spoil blanket sling	Low (< $500)	2.0	Substantial	2.0	Substantial	2.0	6.0	**II**	B: 2013 C: 2006	B: $100 to $1000 C: $350 to $700	B: Injuries from excessive shoveling, mostly backs and some shoulders. Tarps eliminate the need to shovel to backfill. Tarps were stock item in one region of company. Review of EPRI handbook supported making tarps standard practice for all regions. C: labor savings, less back strain, reduce backfill time
3.5	Repair of Primary Jacketing or Secondary Insulation	Gel-filled wrap around damaged portion of cable	Low (< $500)	2.0	Substantial	2.0	Substantial	2.0	6.0	**I**	C: 2001	C: $3	C: saves money by allowing cable to stay in service without replacing entire run
3.6	Pigtailing Concentric Neutral Wires on a Primary Cable	Drill with concentric neutral winder tools and eye bolt	Low (< $500)	2.0	Moderate	1.0	Moderate	1.0	4.0	**I**	A: ND	A: ND	A: ergonomics

Table C-1 (continued)
Survey Data From Handbook 3 (Direct-Buried Cable Tasks)

Handbook 3 (Direct-Buried Cable Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.7	Removing Elbow Terminations	Lever-action pulling tool and shotgun stick	Low (< $500)	2.0	None	0.0	Substantial	2.0	4.0	**III**	A: ND C: 2004 D: ND	A: ND C: $180 D: ND	A: ergonomics C: employee safety, prevents strain/sprain injuries and reduces flash potential D: ND
3.8	Removing Insulation from Secondary Cable	Stripping tool into chuck of drill	Low (< $500)	2.0	Moderate	1.0	Substantial	2.0	5.0	**I**	A: ND	A: ND	A: ergonomics
3.9	Leveling Padmount Transformers	Trailer jack with cordless drill	Low (< $500)	2.0	Substantial	2.0	Substantial	2.0	6.0	**0**			
3.10	Operating a Tongue Jack on an Equipment Trailer	Equipment trailer with spring-loaded jack extensions	High (> $500)	1.0	Moderate	1.0	Substantial	2.0	4.0	**II**	A: ND C: 2005	A: ND C: $400	A: safety, ergonomics C: ease of operation
3.11	Installing a Portable Roadway System	Composite, fiberglass or plastic mats as portable roadway system	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**I**	C: 2008	C: $625 for 10 pads	C: labor savings, employee safety, reduces strains/sprains

Table C-1 (continued)
Survey Data From Handbook 3 (Direct-Buried Cable Tasks)

Handbook 3 (Direct-Buried Cable Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	Task Description	Ergonomic Intervention	Category	Prioritization Score	Category	Prioritization Score	Category	Prioritization Score					
3.12	Digging Through Frost	Frost removal unit containing propane torches	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**0**			
3.13	Excavating to Expose Underground Utilities	Hydro-vacuum system	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**II**	A: 2005 C: 2002	A: ND C: $69,000	A: ergonomics, efficiency C: safe method to expose UG utilities. Reduces worker strain.
3.14	Installing Ground Rods	Slide collar with electric hammer drill	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**II**	A: ND C: 2011	A: ND C: $850	A: ergonomics C: provides lighter tool for breaking concrete. Reduces labor to drive ground rod.
3.15	Pulling Cable Through Conduit	Portable capstan	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**II**	A: ND C: 2004	A: ND C: $1125	A: ergonomics C: allows mechanical lifting to locations that are not accessible to trucks.
3.16	Cutting Cable	Battery-powered cutting tool	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**III**	A: 2016 C: 2007 D: ND	A: ND C: $3700 for cutting ACSR up to 750 MCM D: ND	A: ergonomics C: labor savings and employee safety D: hydraulic or battery cutters for cable larger than service cable

Table C-1 (continued)
Survey Data From Handbook 3 (Direct-Buried Cable Tasks)

Handbook 3 (Direct-Buried Cable Tasks)			Initial Cost (IC)		Labor Savings (LS)		Occupational Health Benefit (OH)		Composite Prioritization Score of Intervention*	Number of Utilities Implementing Intervention	Date of Implementing Intervention	Cost of Intervention ($)	Reasons for Implementing Intervention
No.	**Task Description**	**Ergonomic Intervention**	**Category**	**Prioritization Score**	**Category**	**Prioritization Score**	**Category**	**Prioritization Score**					
3.17	Crimping Sleeves and Lugs	Battery-powered press	High (> $500)	1.0	Substantial	2.0	Substantial	2.0	5.0	**III**	A: 2016 C: ND D: ND	A: ND C: $3400 - 12 ton; $1800 - 6 ton D: ND	A: ergonomics C: labor savings and employee safety D: hydraulic or battery crimper

*Composite prioritization score = IC + LS + OH
A, B, C, and D = site-visit utilities
ND = no data reported in survey

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