ELECTRIC SHOCK FAULT TREE STUDY

Final Report

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Notice

EXECUTIVE SUMMARY

Baker Engineering and Risk Consultants, Inc. (BakerRisk®) has completed the electric shock fault tree workshop, which was conducted on April 26-27, 2018 at the offices of Technical Safety BC (TechSafeBC). During the course of this workshop, a fault tree was developed to evaluate potential causes of electric shock risks, and recommendations were made to address the key causal factors behind those risks.

The generated fault tree for electric shock appears as an attachment in Appendix A. Due to the size of the fault tree, it is not included in the main body of the report.

There were eight recommendations made by the working group for further action. These recommendations appear in full in Section 3 of this report. There were three key causal factors that were identified during the sessions:

1. Although there is a requirement for certification, and a process to certify electrical workers through a recognized apprenticeship program, TechSafeBC's oversight of these programs is limited. TechSafeBC licenses companies and contractors and oversees Field Safety Representative (FSR) training, but it does not retain a record of all certified journeymen or apprentices working in the province, nor does it track the extent of, or content of, continuing education programs. The belief of the workshop participants was that this lack of oversight allows electrical workers and contractors to undertake work for which they lack the appropriate level of knowledge and experience.
2. Concerns about corporate resourcing, oversight, and cultural factors were raised as a potential issue numerous times. Due to the nature of work in the electrical industry, with large numbers of small or independent contractors, the workshop participants believed that a lack of education and understanding on the part of these smaller organizations was contributing to the overall risk in the province. Recommendations were made to develop programs to support and inform smaller contractors.
3. Potential interference with dangerous electrical systems on the part of the general public or untrained workers has always posed a risk. The workshop participants agreed that some type of public outreach program to provide basic electrical safety information would be worthwhile.

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1 INTRODUCTION

On April 26-27, 2018, a two-day workshop was conducted by BakerRisk with TechSafeBC personnel to create a fault tree that studied the risks associated with electric shock in British Columbia. This workshop was a follow-up to a fault tree that had been internally generated by TechSafeBC in 2017, and the second of four workshops conducted by BakerRisk in 2018 covering four different risk topics of interest to TechSafeBC: escalator operation, electrical shock, ammonia exposure and carbon monoxide exposure.

At the beginning of the session, the working group defined the final event to be analyzed as an electric shock to a human or animal capable of causing physical harm. The level of potential harm was not defined, merely that the shock was capable of causing harm. The fault tree generated during this study is included in Appendix A. The original fault tree created in 2017 is included in Appendix B. A full table of all causal factors generated appears in Appendix C.

Section 2 of this report includes a brief overview of the fault tree methodology. Section 3 includes a full listing of all recommendations made by the working group, and Section 4 provides a summary and conclusion for the project.

2 Fault Tree Analysis

2.1 History

Fault tree analyses were first created and performed in the 1960's by Bell Laboratories in the U.S. in order to evaluate the risks associated with the potential inadvertent launching of Minuteman missiles and the potential unauthorized arming of nuclear devices. In the 1970's, the fault tree system was adopted by the U.S. nuclear industry as a method to evaluate the reliability of reactor safety, including potentials for reactor runaway and the release of radioactive materials. It is still used in the U.S. nuclear industry to analyze risks and failure rates of critical systems.

Through the 1980's and beyond, fault trees have occasionally been used in chemical and petrochemical companies to provide detailed risk analyses where less detailed methods such as hazard and operability studies (HazOps) have not provided a clear resolution to risk decisions.

2.2 Basic Method

A fault tree is generated by choosing a specific final event of interest – such as a chemical release in a specific location, or an explosion from a reactor that leads to a fatality. After choosing the final event, the participants in the fault tree study work backwards to identify all of the causes that could lead to that particular final event. In most fault tree studies, each initiating cause is assigned a specific probability, allowing the organization creating the fault tree to identify the dominant cause or groups of causes that led to that final event so that they can be addressed.

Fault trees use logic gates to create a map of sub-causes from the original event to the multiple potential root causes for that event. In Figure 1, the logic gate symbols used in fault trees are shown.

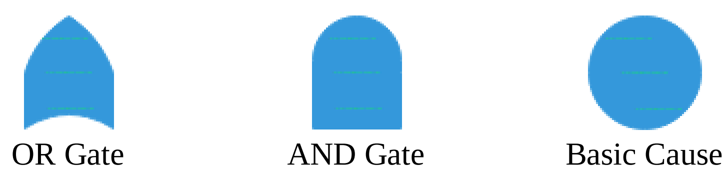

Figure 1. Logic Gate Symbols

Figure 2 shows an example tree created to demonstrate the fault tree map that could be used to identify the failures that could result in a light bulb not turning on.

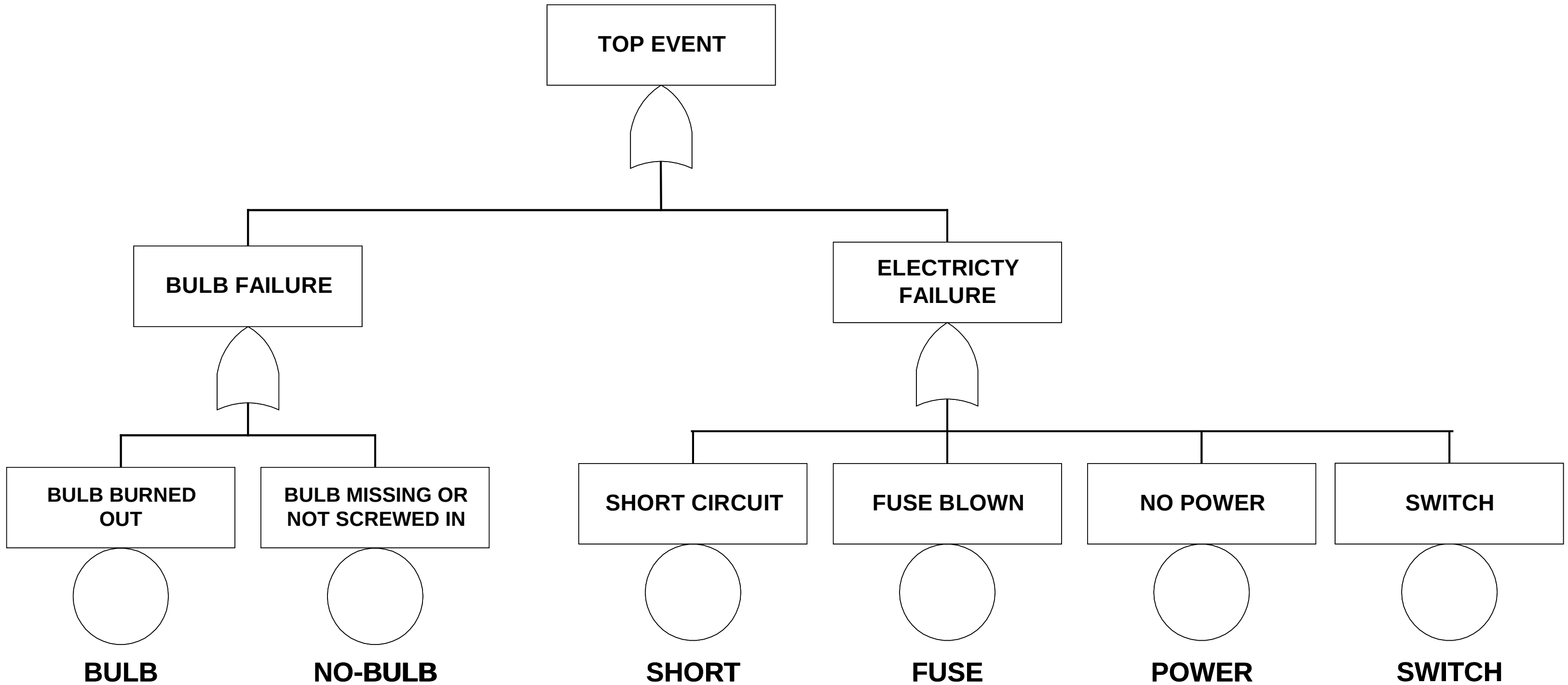

Figure 2. Fault Tree Example – Light Bulb Fails to Light

3 RECOMMENDATIONS

At the conclusion of the workshop, the working group reviewed the fault tree that had been created and identified the key causal factors that appeared in the tree; either factors that were repeated in numerous locations, or factors that were deemed critical by those participating. The group then held a brainstorming session to develop actions and recommendations that could be carried forward by TechSafeBC to reduce the risks associated with electric shock by addressing these causal factors. These recommendations appear in full, below:

1. Consider developing a program to promote the existing reporting processes for incidents and near misses (under both TechSafeBC and WorkSafeBC).
2. Consider developing and including material that covers the existing requirements and method for reporting incidents and near misses at the curriculum level for electrical apprentices, and at other opportunities (i.e., tech talks, FSR courses, AGM, FSR renewals, trade shows, publications, etc.)
3. Consider researching and acquiring more external data sources to support targeted risk treatment activities, including:
    a. Hospital data
    b. WorkSafeBC data
    c. Utility data (BC Hydro, EPCOR)
    d. U.S. occupational data/other jurisdictions (i.e. TSSA, NFPA, ESA, UK)
    e. Municipalities
    f. Suppliers/sellers
    g. IEEE data
    h. IBEW data

4. Consider undertaking a review of the current curriculum for apprenticeship and certification with the intent to develop content to improve understanding of isolation procedures and verification and testing procedures.
5. Consider creating and promoting an e-learning course to address the same content as in recommendation #4. Consider making this a requirement for FSR renewal, as well as making the content available to apprentices/journey people without FSR certification. Consider partnering with industry associations and trainers to allow the material to be widely disseminated.
6. Consider improving the existing oversight model of electrical contractors and asset owners to close the current gap related to journey people not having workplace-appropriate knowledge or training or not maintaining that training. Currently,

FSRs are certified and tracked by TechSafeBC, but journeymen and apprentices are not tracked or directly monitored in any way.

7. Consider creating a general awareness campaign to improve public knowledge of shock risks, similar to the ‘Call before you dig’ program. Consider partnering with other organizations to promote the program as widely as possible.

8. Consider creating an orientation program for contractors/asset owners/operators (potentially tied to issuance/renewal of license/operating permit) that addresses the following issues:
    a. Roles/responsibilities that are associated with each level of authority.
    b. Liabilities associated with owning/operating a business or asset, including the criminal code liabilities introduced with Bill C-45.
    c. The potential consequences related to compliance/performance deficiencies.
    d. Behavioural factors or systems that can contribute to or reduce incidents.

4 SUMMARY

On April 26-27, 2018, a working group formed by Technical Safety BC met to update the fault tree analysis done in 2017 on electrical shock risks in the province of British Columbia. During this workshop, the working group generated a fault tree to identify the causal factors for electrical shocks.

At the conclusion of the two-day workshop, eight recommendations were made to address the common or critical causal factors identified, as outlined in Section 3. The critical factors identified during this workshop were gaps in the existing oversight of trained electrical workers on the part of TechSafeBC, which allows workers who are certified as electrical workers to undertake work that they are not necessarily trained to do. Associated with this gap was the perception of the workshop participants that there was a lack of knowledge on the part of both asset owners and smaller contractors as to their own legal responsibilities and requirements to ensure that electrical safety is properly addressed.

This combination of both a lack of direct oversight to ensure appropriate work qualifications are in place, as well as a perceived lack of knowledge on the part of asset owners and smaller contractors, is indicative of what could be a significant cultural issue underlying the electrical industry in BC. Tied to this cultural issue was the general belief on the part of the workshop participants that near misses or minor incidents are widely under-reported. Shifting the base cultural beliefs and assumptions is very difficult on a wide scale, and it will take a concerted effort on the part of TechSafeBC to improve the existing situation.

APPENDIX A. FAULT TREE

Due to the large size, the fault tree created during this workshop is attached as a .pdf file to this report. The file name is *Electric Shock.pdf.*

APPENDIX B. ORIGINAL FAULT TREE

The original fault tree developed by TechSafeBC is attached as a Microsoft Visio file. The file title is *Event Tree – Electrical Shock*

APPENDIX C. CAUSAL FACTORS

Causal Factor	Number of Appearances
Lack of Duty Holder Oversight	16
Corporate Culture/Accountability	13
Risk Tolerance/Complacency	12
Lack of Process/Procedure	9
Apprenticeship Program Issues	8
Continuing Education	7
Manufacturing Defect/Flaw	5
Lack of Change Control	5
Lack of Knowledge/Training	4
Parts Availability	4
Time/Production Pressure	4
Cost/Time Constraints	3
Vandalism	3
Code Gap	2
Commissioning Error	2
Contractor Size	2
Engineering Review Failure	2
Fire	2
Lack of PM/Inspection Program	1
Personnel Availability	2
Ergonomic Issues	2
Poor Bond/Ground	2
Poor Signange/Fencing	2
Regulatory Review Failure	2
Specification Availability	2
Standard Availability	2
Time Constraints	2
Water	2
Wind/Weather	2
Animal Damage	1
Bypass/Disable Safety Systems	1
Capacitance Effect	1
Chemical/Bio Contaminants	1
Client Pressure	1
Code Changes	1
Contract Requirements	1
Cost Constraints	1
Cost/Supply Constraints	1
Counterfeit Equipment	1
Current Path	1
Design Flaw	1
Egress Constrained	1
Electric Potential	1
Equipment Availability	1
Ergonomic/Environmental	1
External Conditions	1
High Voltage Present	1
High Wind	1
Ice Load	1
Improper Isolation/Breach of Isolation	1
Inadequate Material Control	1
Lack of Asset Control	1
Lack of ground disturbance procedure	1
Lack of Hazard Assessment Training	1
Lack of high work procedure	1
Lack of Requirement	1
Lack of site training	1
Lightning	1
Low/No Load	1
Minimum Amperage	1
Misuse	1
Obsolescence	1
Poor Hazard Awareness	1
Procedures Incomplete/Inadequate	1
Snow Load	1
Supply Management	1
Tool Availability	1
Usability/Comfort	1
Vehicle Impact	1
Wear/Tear	1
Lack of Replacement Strategy	1