Electrical Safety Authority

First Report

Electrical Safety in Ontario

Engineering and Regulatory Group

November 2001

Executive Summary

The rate of electrical fatalities, injuries and fires has been on a decline in the last five years. The trend showed that occupational fatalities far exceeded home fatalities in this period. Utility infrastructure, or specifically overhead powerline plays a significant role in electrical fatalities. It accounts for half of the electrical related deaths. Electrical occupational injuries reflect the number of people and activity in their respective industry. Based on the number of serious injuries to minor ones, electrical work in construction industry proves to be most hazardous of all industry. Electrical fires occur mostly in residence with major cause attributed to misuse of cooking activities and equipment.

Foreword

Electricity is an essential part of today's living and is an integral part of our civilization. As much as electricity enhances our lives, if used improperly, it can also do harm. Electrical fatalities, physical injuries and fires are evidence of that. This report is compiled based on information and data provided by the Workers Safety Insurance Board of Ontario (WSIB), the Ontario Ministry of Labour's (MOL) fatality, injuries and critical injury quarterly reports, the Office of the Fire Marshall's (OFM) data, Statistic Canada, Safety Workplace Agencies' data, the Ontario Coroner's Office 1992-1999, and Electrical Safety Authority (ESA) internal fire and accident reports. WSIB data includes burns that were not electrical in nature. Some portions of the information are imbedded in the pool of data in such a way that it was difficult to distinguish to be separated. Vehicle fires and suicides included in the OFM data and the Coroner's Office report was excluded from the report.

1. 0. Purpose

The purpose of this report is to;

- Identify injuries, fatalities and property damage of an electrical nature
- Identify trends and areas of concern in electrical safety and potential deficiencies in the electrical safety infrastructure
- Provide conclusions and recommendations on how electrical safety can be improved in Ontario

The report will begin by providing readers with an overview of electrical injuries, fatalities and fires as a whole. The next part of the document presents detail of the data, with a closer look at causes and nature of electrocutions, occupational (electrical) related fatalities and injuries. Then, the document provides detail of electrical fires, the fatalities and injuries that results and their relative prevalence. Summary and conclusion puts the document in closure.

2.0. Overview

2.1. Injuries and fatalities

In the last decade, Ontario has experienced a decline in the rate of fatalities, injuries and fire of electrical nature. The Province suffered 67 electrical fatalities between 1996 and 2000, averaging 13.4 fatalities per annum (p.a). In this period, the Province's electrocution rate[1] has decreased from 1.44 to 0.77, a 47% drop. In comparison, US electrical fatality rate for 1995-1998 declined from 2.13 to 2.03. Ontario experienced nine electrocutions in year 2000, and at the time of writing, there were seven electrocutions in year 2001.

[1] Per million population

Figure 1

Electrical Fatality 1995-2001

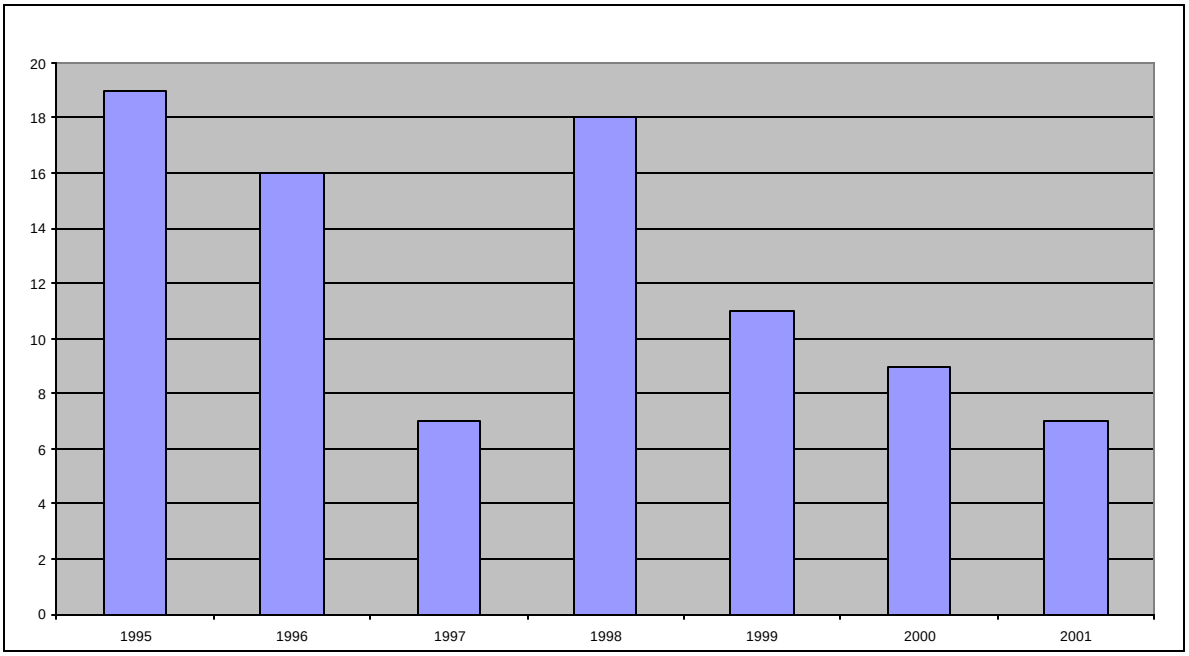
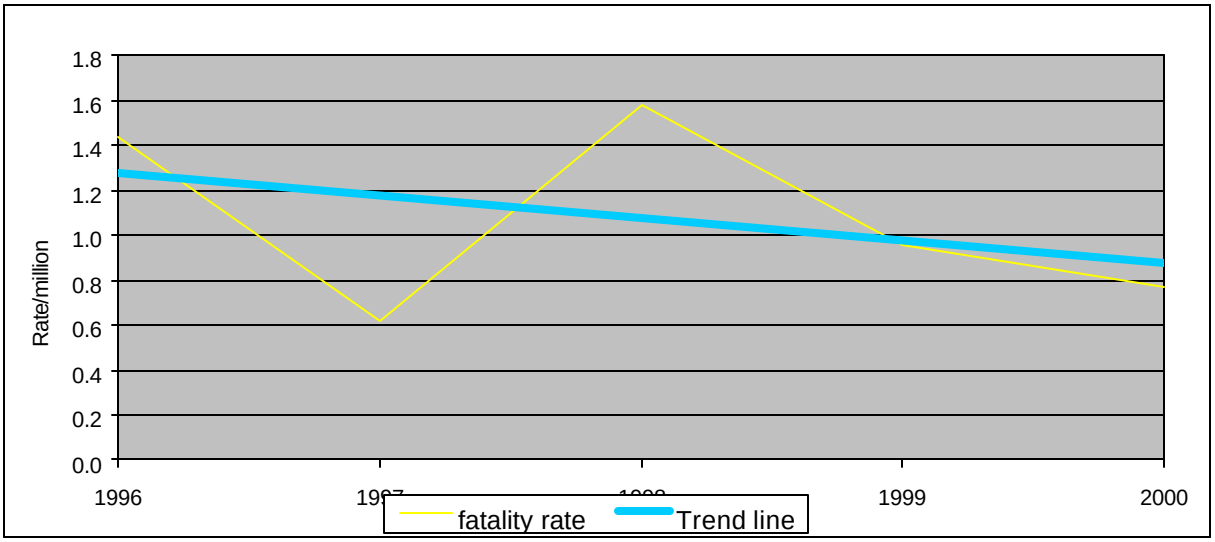


Figure 2

Electrical Fatality Rate 1996-2000

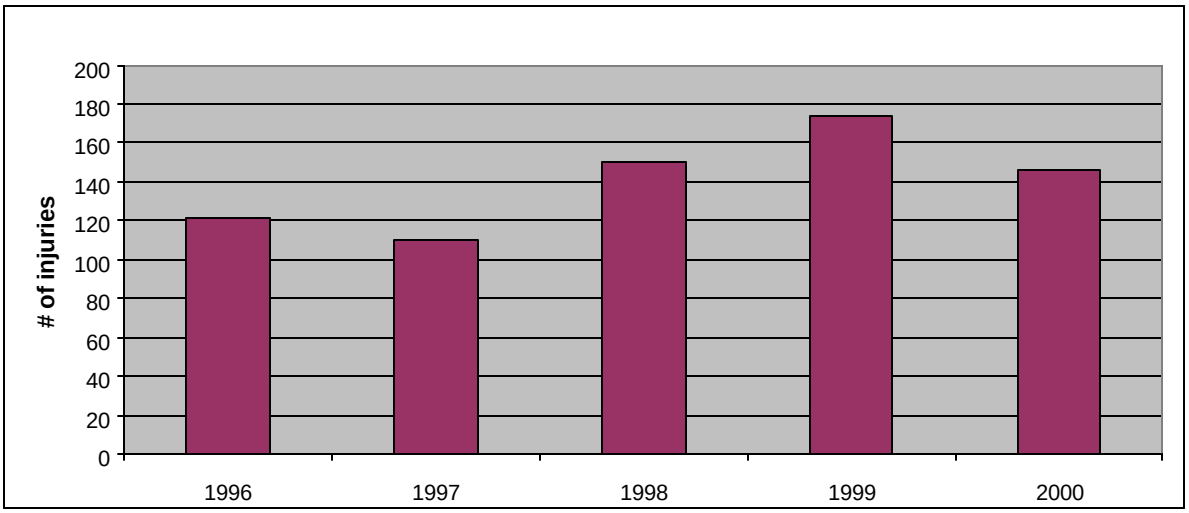


Between 1996 and 2000, workplace injuries of electrical nature have risen from 121 to 146 injuries per annum (p.a.). In comparison, the total of all occupational injuries and illnesses filed by the Workers Safety Insurance Board (WSIB) have increased from 345,606 claims to 364,069 claims in the same period. To put it these numbers in perspective, electrical injuries represented roughly 0.04% of all occupational injuries in Ontario.

The number of electrical injuries was then compared to Electrical Safety Authority's (ESA) *Application for Inspection* issued (AFI)[2]. The reason for comparing AFIs to number of injuries is as follows; AFI reflects work in the electrical field in Ontario since all electrical installations in Ontario requires an AFI. All things being equal, the number of injuries should be proportional to level of work activity i.e. when there is no work, there should be no injury. When work activity increases and there is no change in safety measures, injury should increase proportionally. In this case, injury rates have actually declined from 7.79 injuries/AFI in 1996 to 5.26 in 2000, a drop of 32 percent.

Figure 3

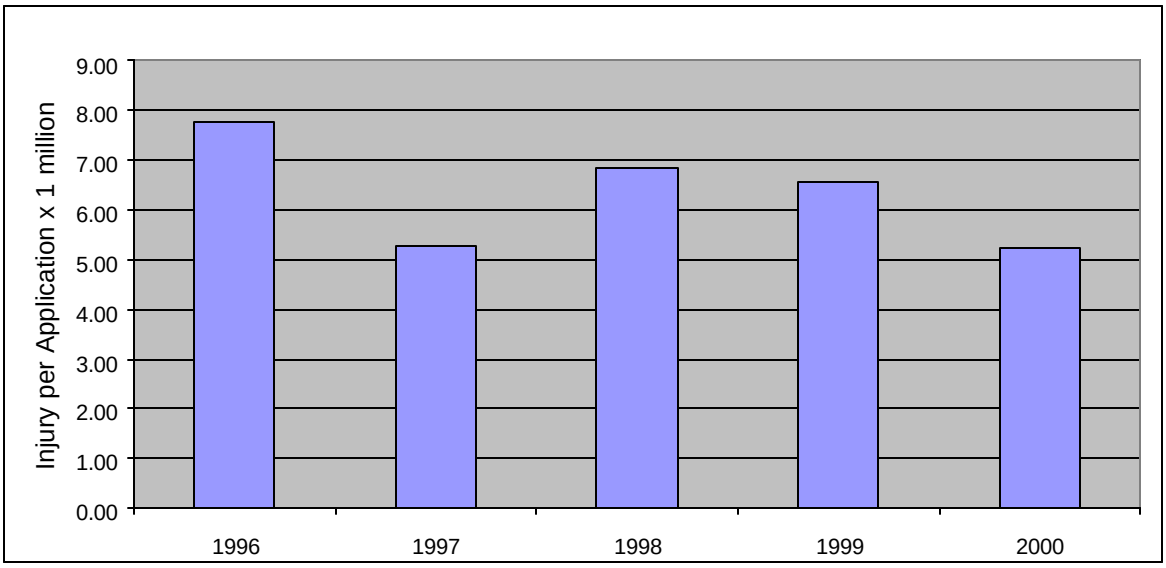
Occupational Injuries (Electrical)



[2] AFI's are permits issued by ESA for all electrical work in the Province of Ontario. It is a requirement under the Ontario Electrical Safety Code.

Figure 4

Injury Rate per ESA Application for Inspection



Between 1996 and 2000, electrical related injuries cost the province $7.4 million in compensation. Annual cost of these injuries has decreased from $1.8 million in 1996, to $0.8 million in 2000. Cost per electrical injury has also decreased in the same period from $14, 947 to $5,345.

In addition to compensation cost (often referred to as direct cost), injuries affect society and community. To start with, there is a loss of production at the time of accident. The severity of the injury may result in trauma to co-workers, family and friends. Trauma goes further into additional loss of productivity after the accident, not to mention low morale, and loss of trust. Upon return, the injured worker may require modified work. In addition, the company would most likely bear the fines levied by the WSIB for the decline in safety performance. Prosecution and/or fines by the Crown for violating the Health and Safety Act and Regulations could also follow. The result is increasing operation cost and loss of public image. In short, injuries make it difficult for a company to compete. Indirect cost of injuries, more specifically electrical injuries cost the society 5 to 10 times the direct cost of the injury[3]

[3] http://www.workcover.com/training/elec-cost.html#indirect

Figure 5

Total Cost of Electrical Injuries

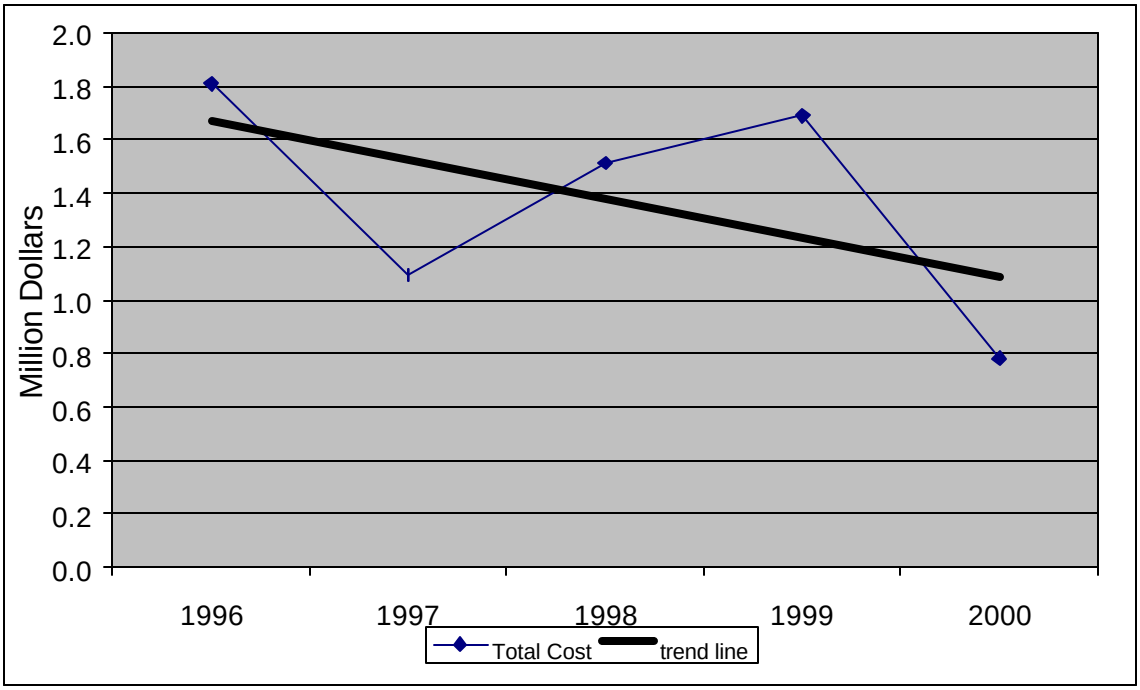
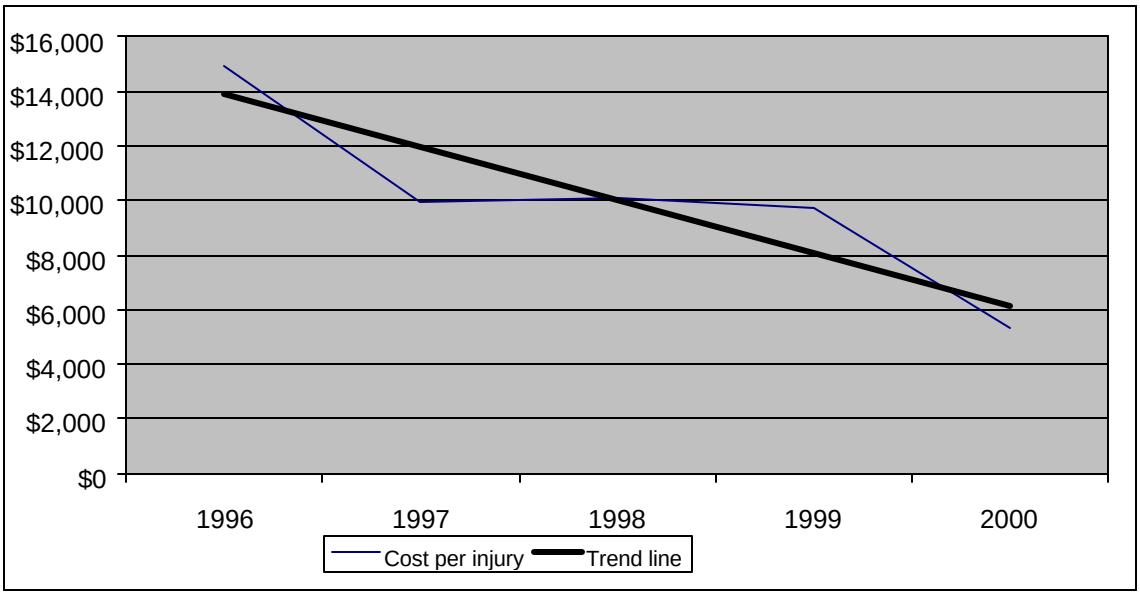


Figure 6

Cost per Injury



2.2. Electrical Fires

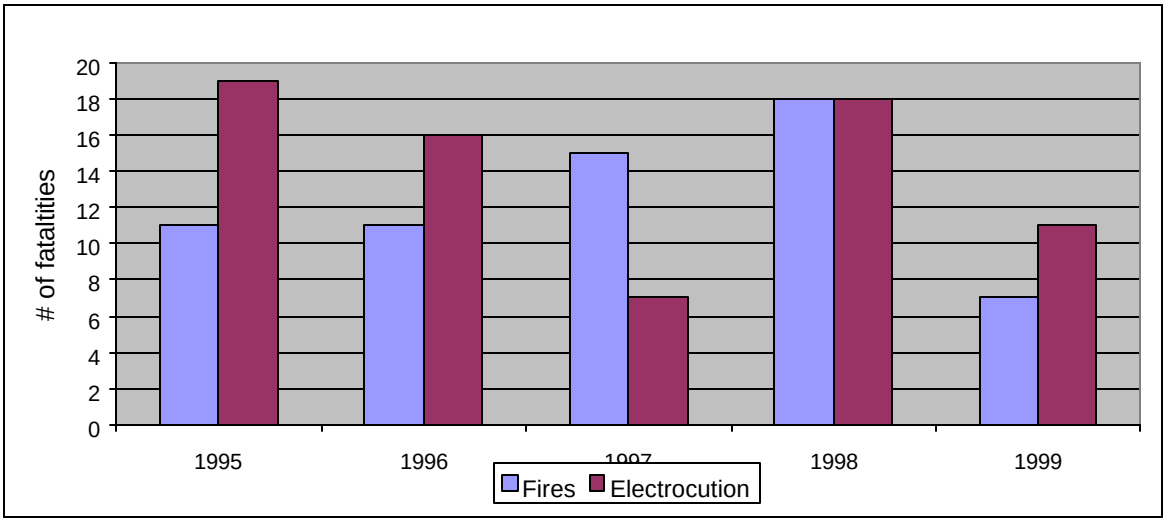
There were 24,775 electrical fires[4] in Ontario between 1995-1999; eleven percent were electrical in nature. The number of fires has decreased by 20% in the five-year period and electrical fires have also decreased at the same rate.

Electrical fires have cost the province $279 million in the five-year span, a $54 million average p.a. and an average cost of $15,000 per fire. With the exception of 1999, cost of fire had been on a downward trend, starting at $62.7 million in 1995 decreasing steadily to $52.9 million in 1998 and rising to $60.3 million in 1999. Whether the 1999 figure is an anomality, it remains to be seen.

The number of electrical fire fatalities had been fluctuating for the same period as can be seen on figure 7. Injuries resulting from electrical fires have decreased from 270 injuries in 1995, to 172 in 1999.

Figure 7

Fire Fatality vs Electrocution



[4] Electrical fires in this document are defined as fires with electricity as the confirmed source of ignition.

3.0. Electrical Fatalities and Injuries

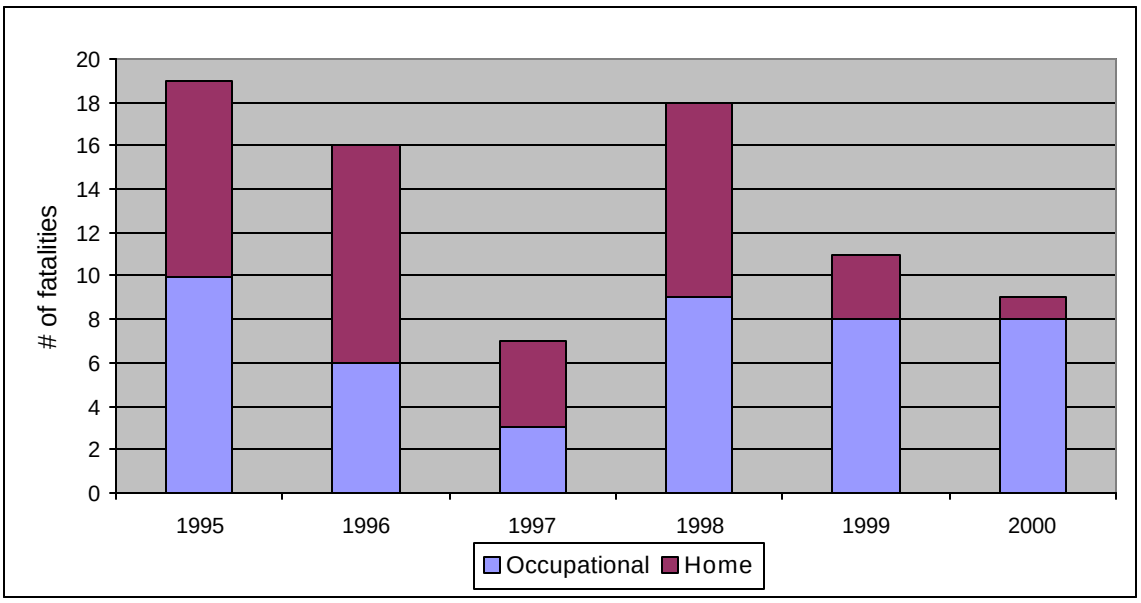
3.1. Electrocutions

Of the 61 electrocutions in 1996 to 2000, thirty-four occurred in the workplace and 27 were home related. Fatalities involving utilities infrastructure[5] represented 50% of all electrocution cases in Ontario in that period.

Fatalities from 1999 to Oct 2001 were all males.

Figure 8

Electrical Fatalities – Home vs Occupational



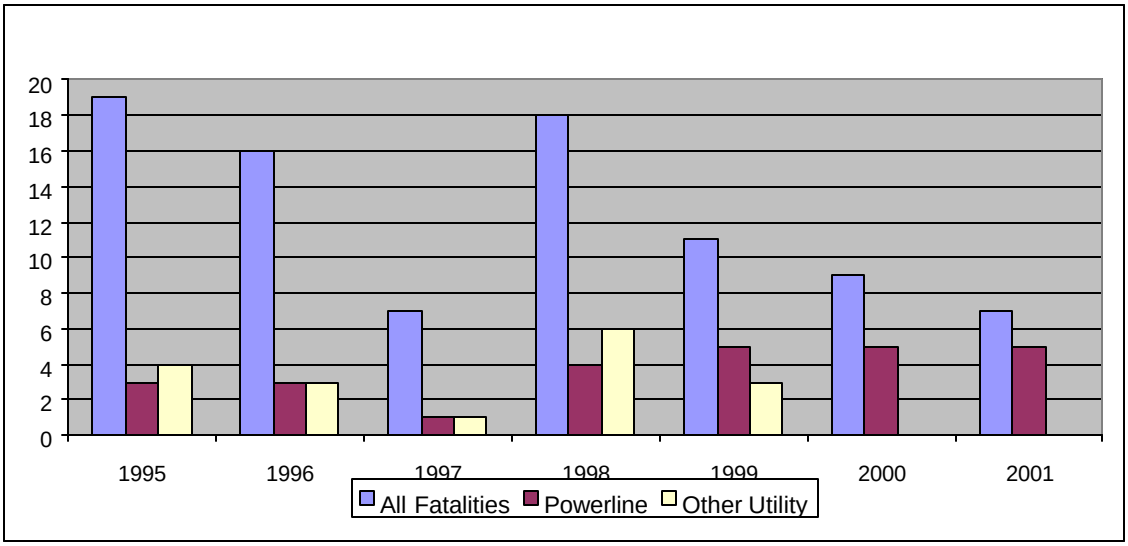
Accidental contact with powerline accounted for seventeen or 28% of home and work fatalities. The number of electrocutions from powerline contacts has not improved in the last decade as illustrated in Figure 9. In the last three years, fatalities by overhead powerline contact accounted for no less than half of occupational fatalities caused by electricity. Contact with metal ladders and aluminum poles were most prominent in powerline fatalities. In utility infrastructure fatalities, there were only three fatalities involving utility personnel

[5] Utility infrastructure is defined as powerline, transformer/transformer station, distribution

between 1996-2000. It should be noted that when looking at electrical fatalities as a whole, workplace fatalities have outnumbered home fatalities in the last three years. Moreover, the percentage is getting larger. In short, workplace electrical fatalities have become more common than home electrical fatalities

Figure 9

Comparison of All Electrical Fatalities vs Fatalities by Utility Infrastructure



3.2. Occupational Fatalities and Injuries

Data for occupational fatalities and injuries were based mostly on MOL and WSIB data. WSIB data is limited that it does not include comments on how injuries occur. MOL data was restrictive in most cases, as the accident report only includes one paragraph of the event. Age, gender and occupation are often missing in the information provided by both parties. Work process and practice is not mentioned. As a result, determining root-cause is difficult.

When an injury occurs in the workplace, WSIB records the injury and apply the record against the employer whose worker suffered the injury. It does not apply the injury against the site where the injury occurred. For example; if a

construction company was retrofitting an automotive plant and the construction company suffered an injury while working in that plant, the injury record goes against the constructor, not the automotive plant. MOL lays charges on fatalities and injuries the same way. The exception is; MOL may lay charges against the automotive plant if it deems that the plant is negligent and was seen as partly responsible for the injury.

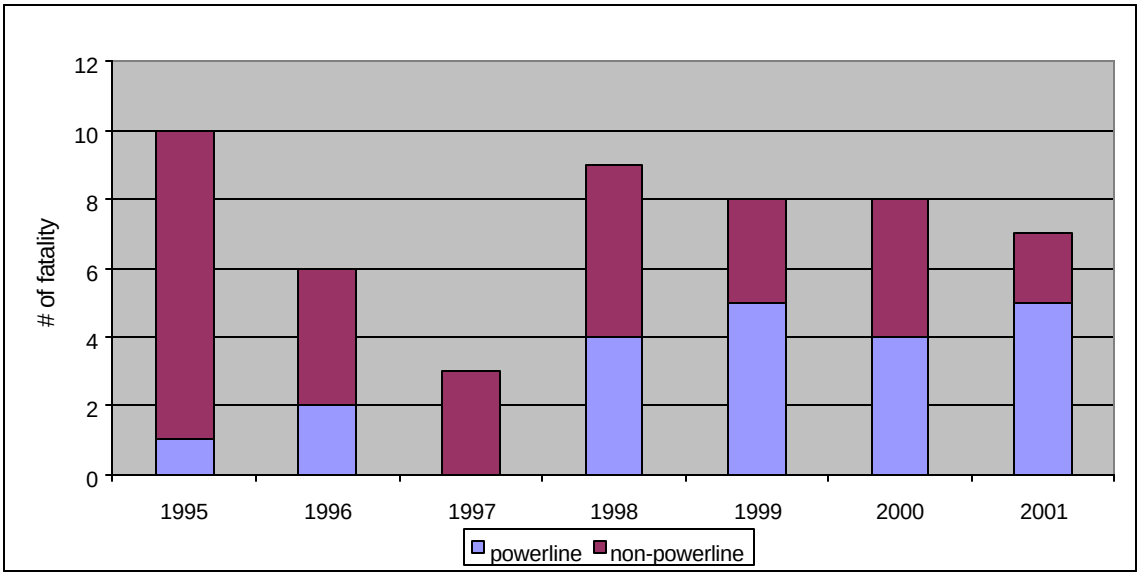
Fatalities

There were 34 occupational fatalities of electrical nature between 1996 and 2000. Sixteen involved working with energized equipment (victims were aware that the lines were energized[6]), fourteen from powerline contact.

Data from 1999, to Oct 2001, indicated that 72% of electrical fatalities occurred outdoors and 66% involved overhead powerline contact.

Figure 10

Comparison of Powerline vs Non-Powerline Fatalities



[6] according to MOL investigation of the respective fatalities

Ladders were the most prevalent equipment involved in occupational fatalities (27%). They were involved in 42% fatalities with overhead wires. Ministry of Labour investigation revealed that less than half of these ladder fatalities were the result of workers losing control of the aluminum ladder while moving or placing them into position. Half of the occupational fatalities involve voltages higher than 240 volts.

Table 1

Occupational Fatalities, Accidents and Incidents[7]

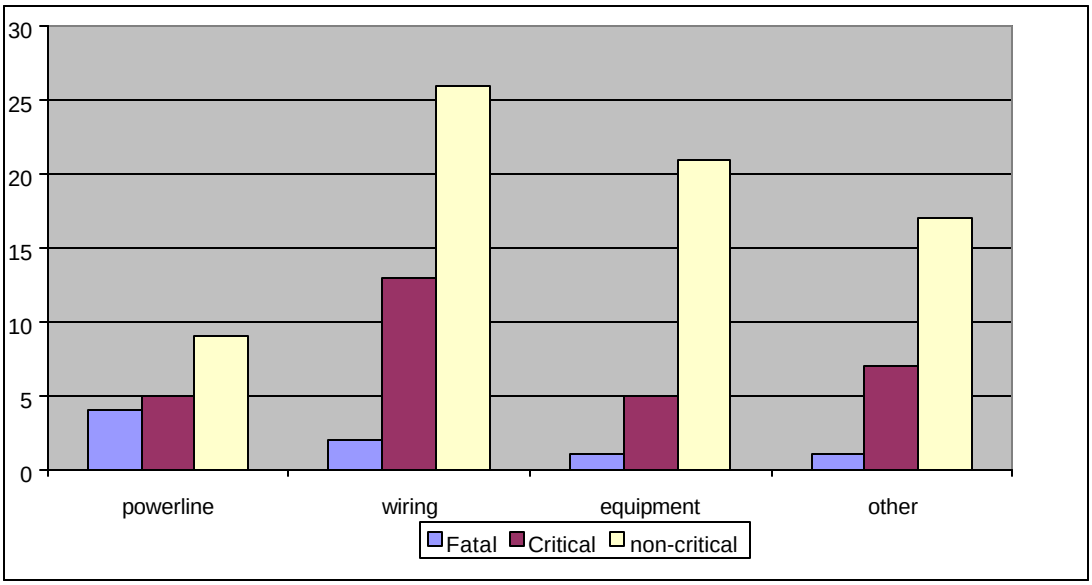
Year	Fatal	Critical[8]	Non-critical	Powerline contact
1998	9	34	52	128
1999	8	34	83	115
2000	8	30	73	122

MOL tabulated electrical accidents are shown on Table 1 above. Figure 11 illustrates the relationship between severity of injury and nature of electrical contact. Figure 11 clearly shows that when powerline contact resulted in an injury, the injury is more likely to be critical.

[7] Ministry of Labour Summary
[8] Defined as injuries where there is a loss of consciousness, loss of major limbs or loss of a large amount of blood.

Figure 11

Occupational Injuries by Severity

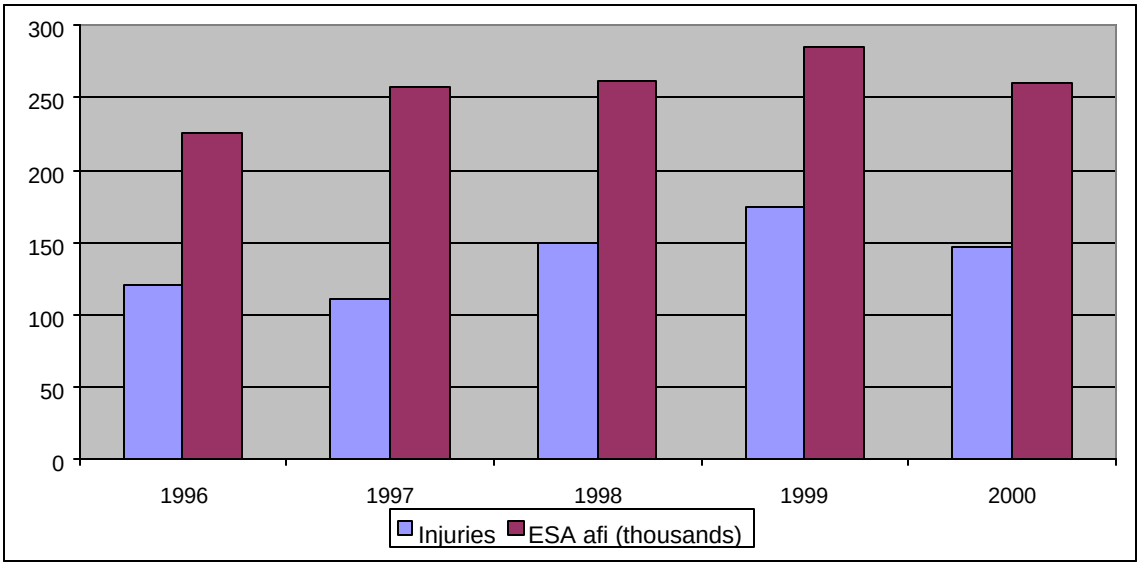


Injuries

Based on the number of AFIs, electrical work had been increasing steadily since 1996, peaking in 1998 and 1999 and on a decline in year 2000. The number of occupational injuries had basically followed the same pattern.

Figure 12

ESA AFI vs Occupational Injuries



Manufacturing and services represented the largest number of electrical injuries of all occupational categories, followed by construction and non-private[9] industries. Industries with most electrical injuries are listed on Table 2.

Table 2

Electrical Injuries and Industries

Industry	Percentage of Injuries
Manufacturing	25%
Service	25%
Construction	14%
Non-Private	10%
Health Care	5%
Automotive	5%

It should be noted that total cost of compensation for manufacturing and service industry were not the highest. Construction had the distinction of being the most costly in terms of total cost and average cost to the industry. Total count of electrical injuries for construction was only half that of manufacturing or service industry. *Yet, construction injury total cost exceeded manufacturing by 45% and almost doubled that of the service industry*. *Cost per injury in construction was twice that of non-private industry and triple that of the remaining top three industries*

[9] Non-private are municipalities, fire department, police

Table 3

Cost of Injury in Industries

	Occurrence	Total Cost	Average Cost/ injury
Manufacturing	194	$1,133,116	$5,841
Service	196	$846,856	$4,321
Construction	108	$1,637,472	$15,162
Non-private	77	$549,941	$7,142
Automotive	38	$166,814	$4,390

Automotive – Companies that manufacture automobiles or manufacture largely automotive parts

Construction – Contractors that build and renovate. Contractors who retrofit manufacturing facilities are considered construction companies

Health Care – Hospital, medical care

Manufacturing – Companies that manufactures metal, hard composites.
Service Industry – Hotel, food, housekeeping

Non-Private – Police, municipalities, ambulance services

Type of Injuries

A third of electrical injuries in the workplace were the result of electrical contact from machinery, followed by contact with wiring and transformers, contact with hot objects, and contact with electric current (non-specified).

When examining industry profiles according to the type-of-injuries, manufacturing and non-private have identical profiles as all industries combined.

Compared to all industries combined, the service industry has the same percentage of contact with electric contact from machinery, while contact with hot objects or substations is more prevalent in this industry (22% as opposed to 12% for all). In turn, the frequency of contact with transformers and wiring is much smaller in this industry at 13% (compared to major industry's average).

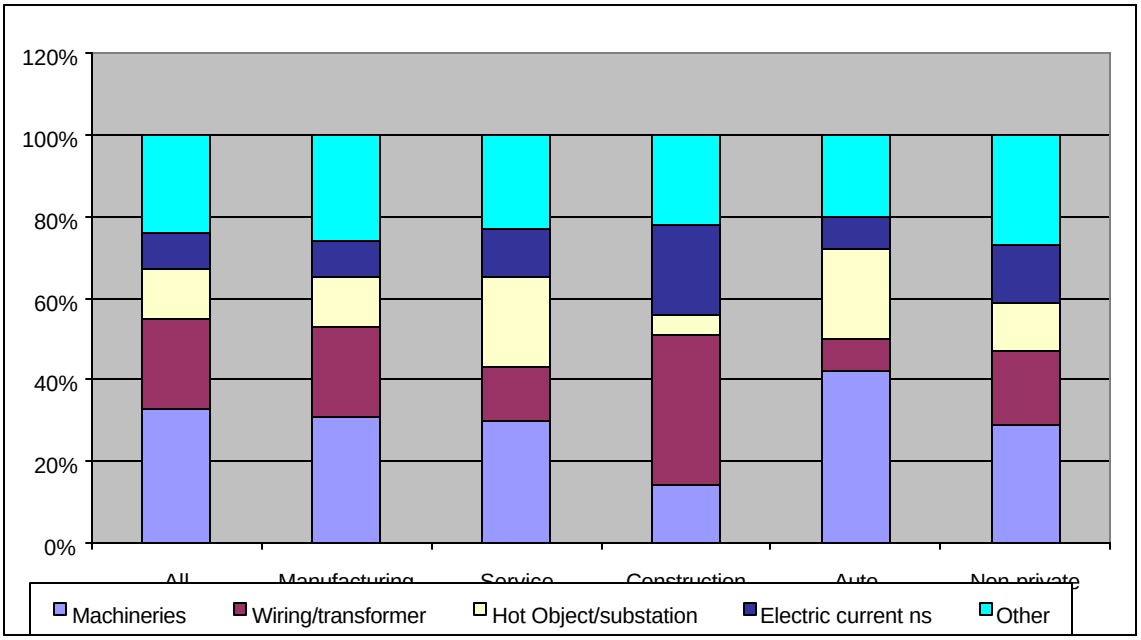
Construction has a different profile all together. Only fourteen percent of their injuries were the result of contact with electrical contact from machinery. Contact

with wiring/transformers formed the largest of type of injuries at 37% while contact with electrical current (non-specified) represented 22% of their injuries. Note that the electrical sector of the construction industry is still one of the safest according to WSIB rating[10]. Unfortunately, occupation of the injured (whether they are electricians or other trade) could not be verified due to lack of information.

Contact with machinery accounted for 42% of electrical injuries in the automotive industry, followed by contact with hot objects/substation (22%), and wiring/transformers at 8%.

Figure 13

Electrical Contact



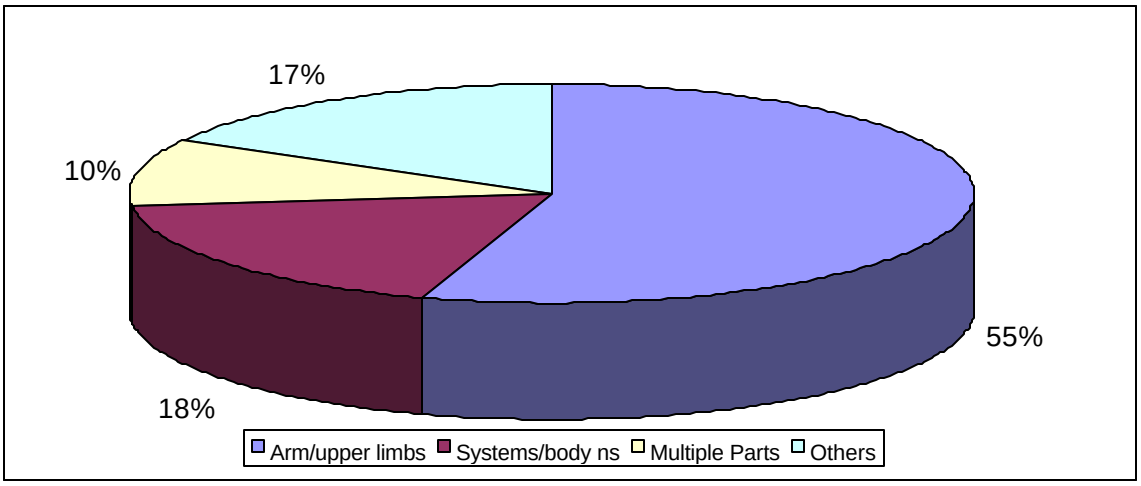
[10] reflected by the lowest construction rating for the sub-industry type in the construction sector by WSIB. Rating is the monies collected by WSIB based on historical injury/safety performance.

Body-part Injured

Figure 14 illustrates the breakdown of body-parts-injured in electrical accidents. Upper limbs, hands, shoulders, fingers, wrists, upper and lower arms represented the largest percentage of all body parts injured at 45%, followed by systems, body not specified[11] (18%) and multiple body parts (10%). When individual industries were examined, they all had the similar body-part-injured profiles.

Figure 14

Body-Parts Injured



- Others in the graph above represented foot, toes, nervous system, respiratory system, lower limbs, torso and other body parts that individually did not exceed 2% each.

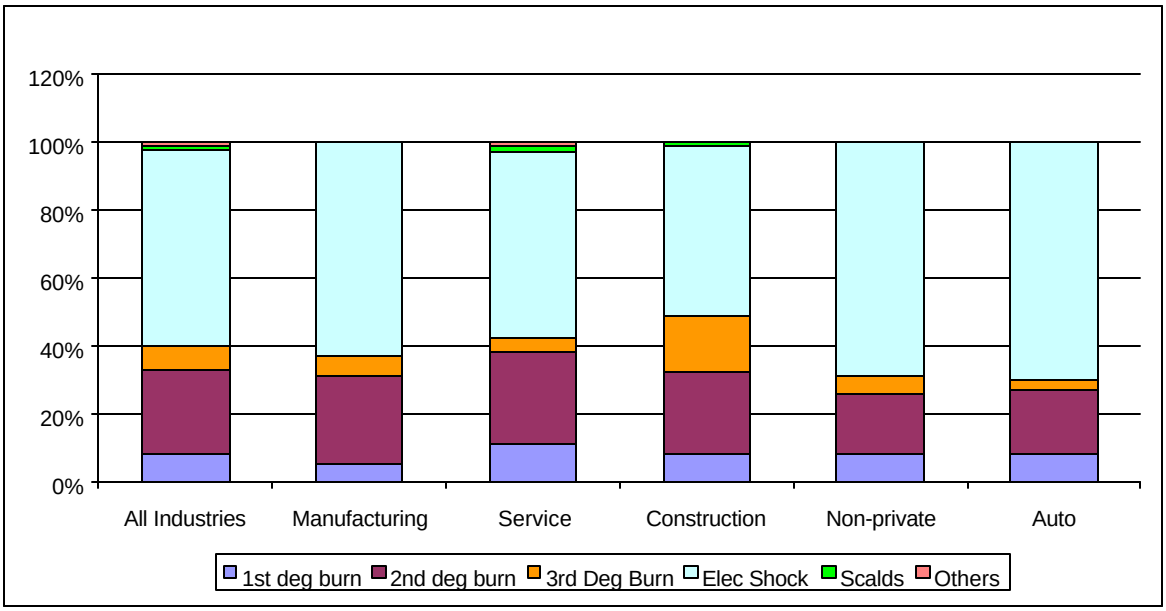
Nature of Injury

Overall, the largest electrical injury in the workplace is electric shock at 58%, followed by second-degree burns at 25%, first-degree burns at 8% and third-degree burns at 7%.

[11] Systems, body not specified are items such as urinary system, gastronomic system, breathing system.

Figure 15

Injury Type



Compared to all industries combined, manufacturing, auto and non-private industries have larger percentages of electric shock injuries but smaller third-degree electric burns. Prevalence of second-degree electrical burns is even smaller in auto and non-private industry than the overall average. The construction sector has twice the prevalence of third degree burns than any other industry at 17*%. The severity of these injuries is reflected in cost per accident and total compensation cost for construction*.

4.0. Electrical Fires

This section of the report is based solely on OFM data. OFM reports fire accidents from ignition-source perspective; source of fire, the device that started the fire, cause of fire, object first ignited. As with MOL and WSIB data, descriptive information is missing to provide root-cause of the accidents.

The 1995-1999 statistics indicated that stoves and range-top burners were involved with 35% of electrical fires. Electrical distribution systems[12] were the

[12] Distribution system are electrical panels/ fuses, wiring

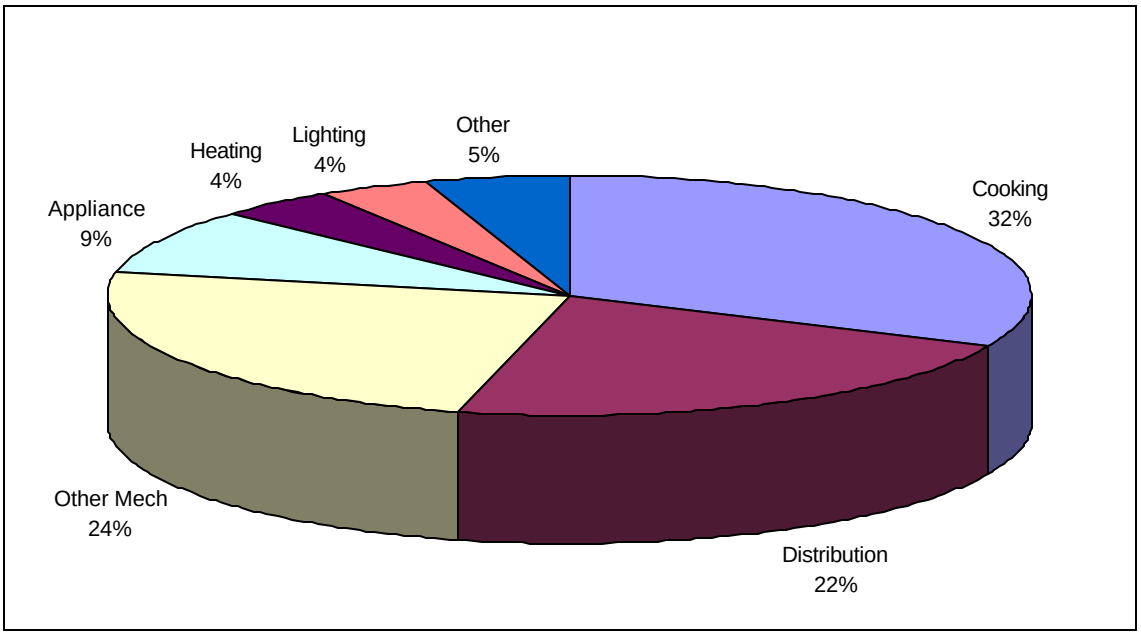
second predominant source at 11%. The rest varied from appliances, space heaters, ovens (5%, 4% and 4% respectively).

Source of Ignition/ Fire Started By

Fires started by cooking equipment represented the largest number of electrical fires, followed by 'other' electrical mechanical fires and electrical distribution equipment.

Figure 16

Source of Ignition



Cooking fires were resulted mostly from misuse of cooking oil, cooking left unattended or clothing catching on fire. These figures are supported by 'Possible Fire Cause' (Figure 17).

'Other mechanical' on the Figure 16 is a mix-match category classified by the OFM. These items vary from moving parts, pumps to motors of various devices. Data from these fires are so widespread in its fire causes or object ignited with. Without additional detail, it was difficult to find a common thread and pinpoint one (or two) problem.

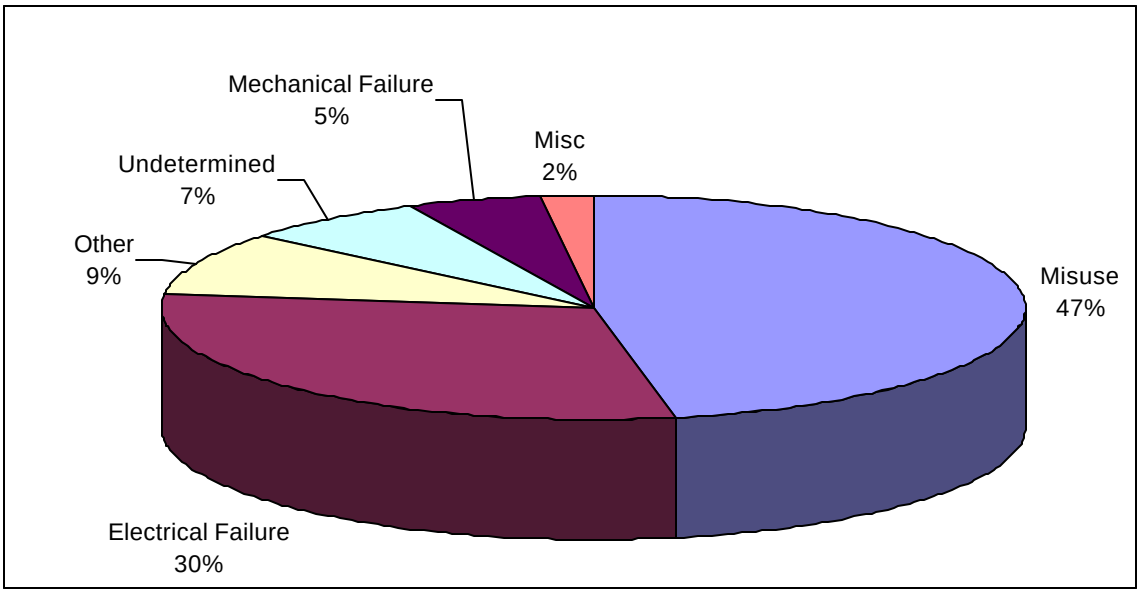
Examination of fires started by electrical distribution revealed that 39% started with electrical wiring insulation. It was followed by interior wall/ceiling (10%), agricultural product and structural members (5% each) The rest were evenly distributed amongst various items such as clothing, rubbish, plastics, cardboard, liquid, insulation and other items, none of which added to more than 5% each.

Cause of Fire

The OFM cited misuse/mishandling of equipment/ignition source as the cause of 47% of fires. Electrical failure was the second most prevalent cause at 30%. Misuse was the primary cause of fires started by cooking. When examining electrical failures, twenty-two percent were attributed to distribution equipment, nineteen percent to circuit wiring, twelve percent to cord, cable for appliance and termination (including switches, receptacles and lights) as sources of failure.

Figure 17

Possible Fire Cause



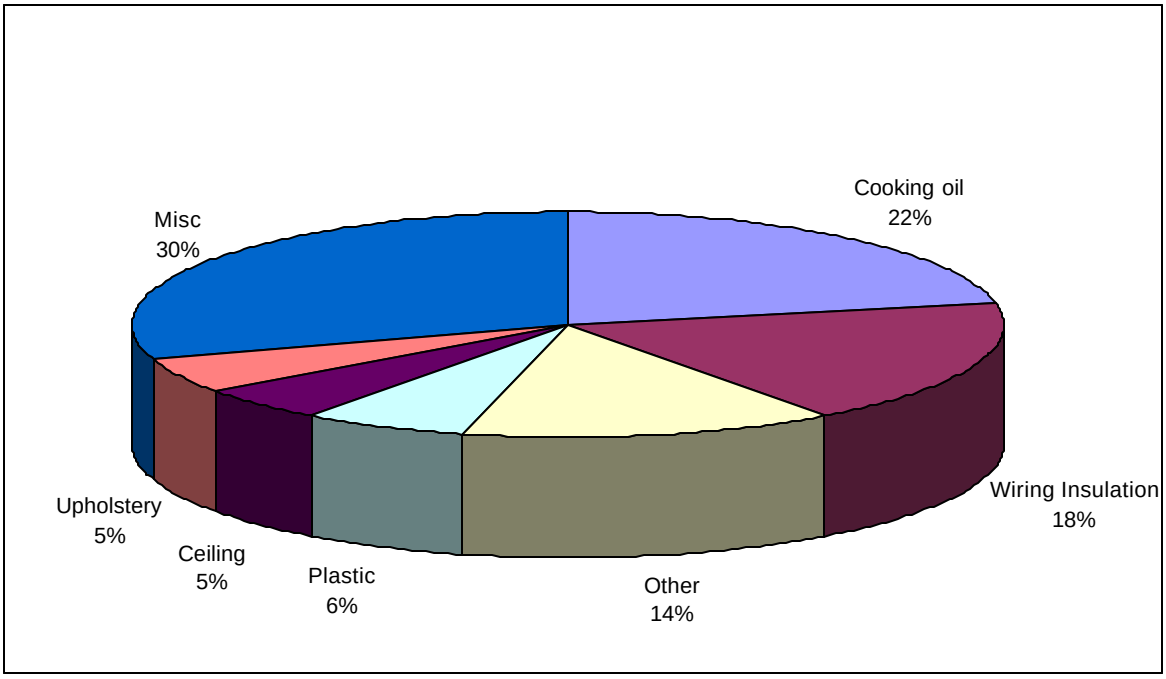
*Others are categories not defined by OFM in their database

Object First Ignited

Cooking oil and other flammable liquids accounted for a third of 'first-object-ignited', followed by electrical wiring (18%). Consistent with above figures, misuse was the leading cause of fire with cooking oil while wiring insulation fires were attributed to electrical failure.

Figure 18

Object First Ignited



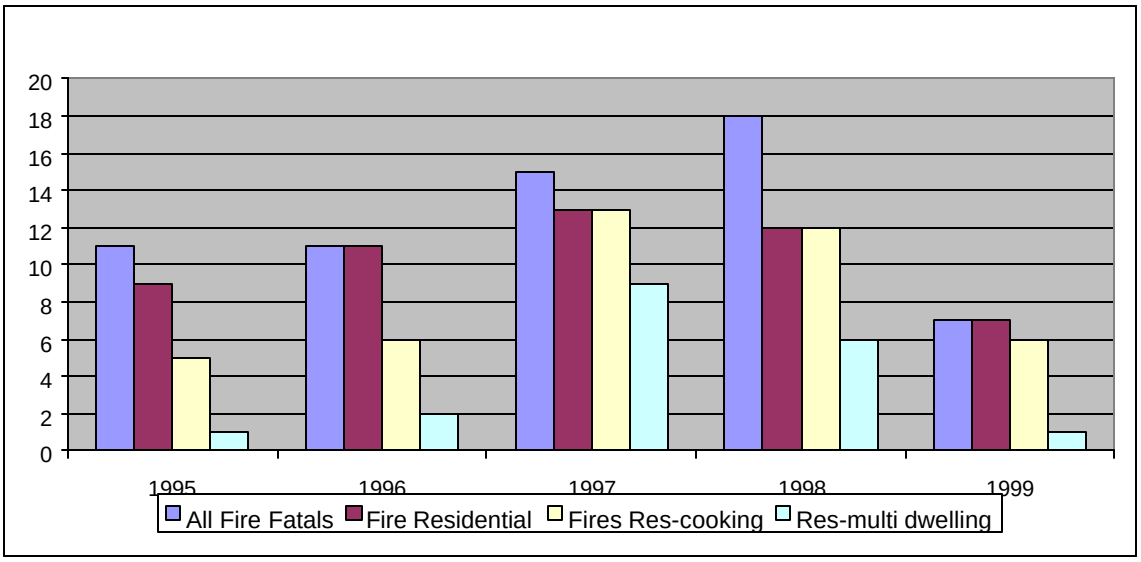
*others are items not classified by the OFM database, miscellaneous items such as upholstery, paper, soft goods, agricultural products, structural members, multiple object or material – none had a prevalence more than 3%

4.1. Electrical Fire Fatalities

Between 1995-1999, eighty-four percent of all electrical fire fatalities in Ontario were residential . Sixty-eight percent of fire fatalities were the result of cooking appliances. When examining residence fatalities, fatality caused by cooking appliance were even more prevalent at 81%.

Figure 19

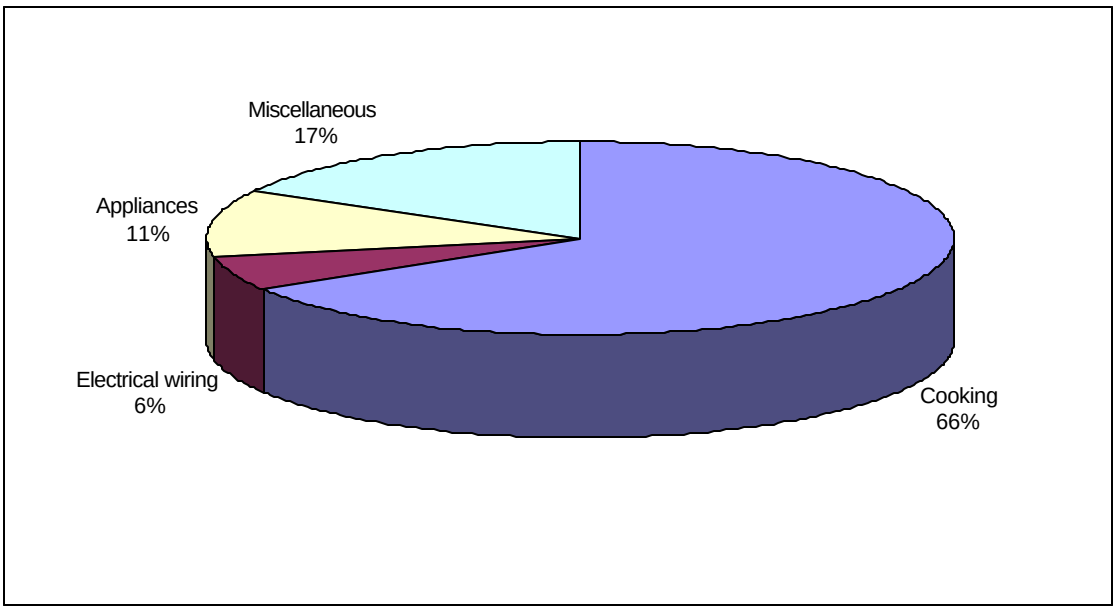
Electrical Fire Fatalities



The profile of fire fatalities is as shown below, sixty-six percent is the result of cooking, eleven percent electrical wiring, and 6% appliances.

Figure 20

Electrical Fire Fatalities – Ignition Source

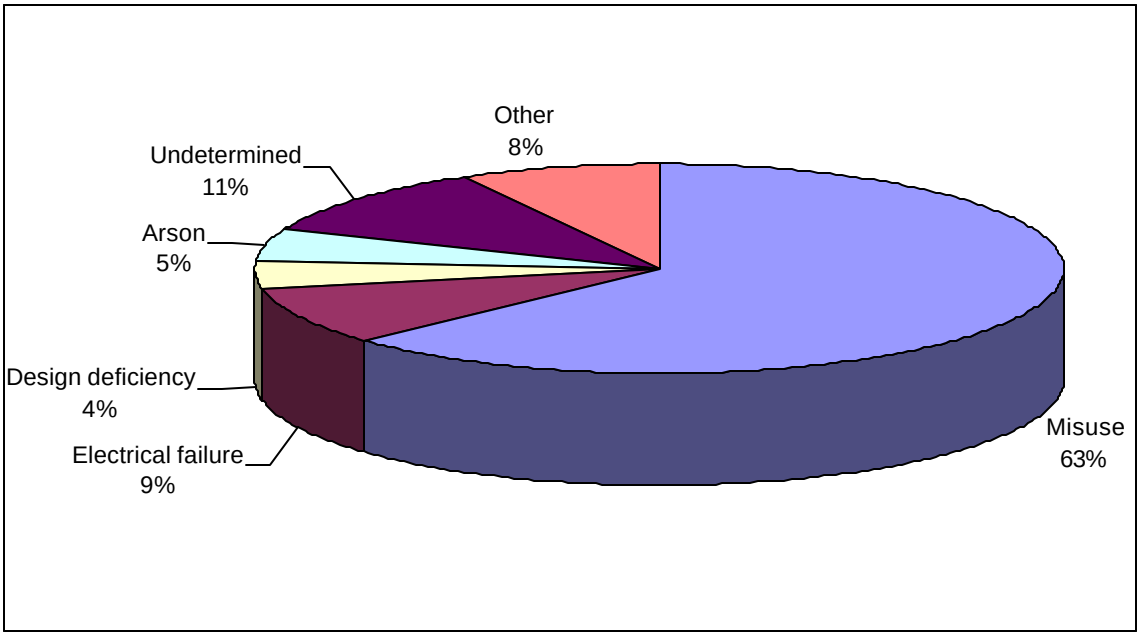


Cause of Fire

Sixty-three percent of electrical fires were the result of misuse, followed by electrical failure, arson and design deficiencies. Eighty percent of misuse fatalities involved cooking and clothing material. Electrical failure was mostly distribution equipment.

Figure 21

Cause of Fatal Electrical Fires



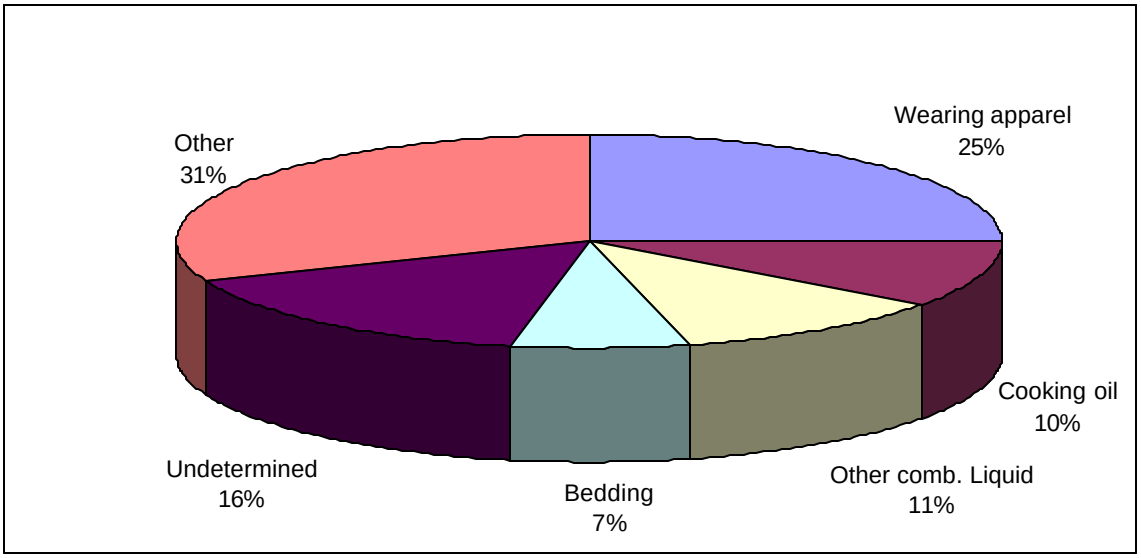
*Others are causes not classified by OFM in their database

Object First Ignited

Fatal electrical fires were investigated according to object-first-ignited. It was found that clothing was most predominant in the category, followed by cooking oils and other flammable liquids and bedding. The distribution is shown on Figure 22.

Figure 22

Electrical Fire Fatalities – Object 1st Ignited



*Others are items such as wood, cabinetry, electrical wiring insulation, upholstery, gases, plastic and other numerous substance, none of which as individual items, accounted for more than 5% of the total.

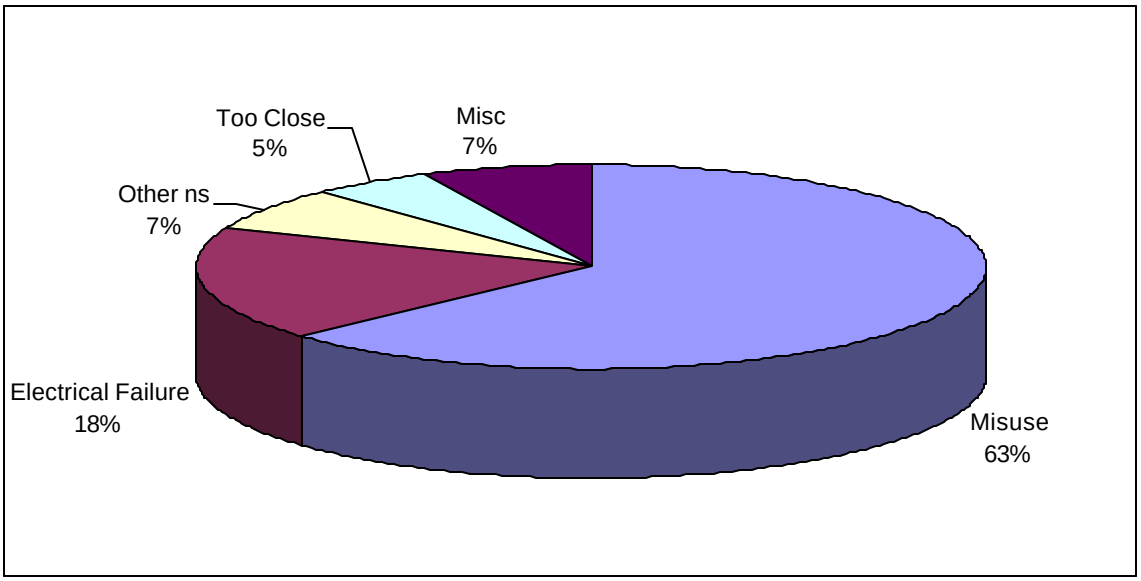
The data is broken down further, looking at fires with 'object-first-ignited' involving ranges and stoves. The number of fatalities caused by clothing igniting showed to be 29%, flammable combustible liquid, 19% and cooking oil, 17%.

4.2. Electrical Fire Injuries

Injuries caused by electrical fires were mostly the result of misuse of ignition source (63%), electrical failure (18%), other (7%) and too dose to combustible (5%). Misuse fires were predominantly involved with cooking while electrical failure was mostly distribution equipment and wiring.

Figure 23

Fire Injuries – Possible Cause



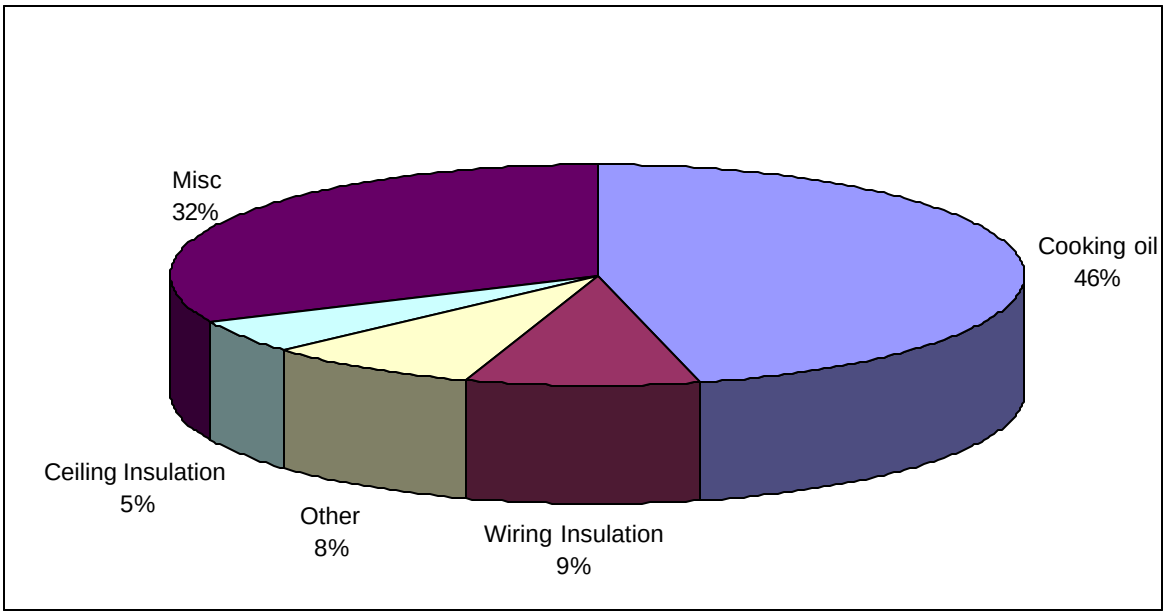
*Other ns are causes not classified by OFM database, while miscellaneous are causes such as installation deficiency, design deficiency, arson, and vandalism, each did not exceed 2% in prevalence.

Object First Ignited

Cooking oil were cited as most predominant in object-first-ignited (46%), followed by wiring insulation (9%), other (8%), wall and ceiling insulation (5%). Misuse was the cause for almost all cooking oil fires.

Figure 24

Fire Injuries – Object 1st Ignited



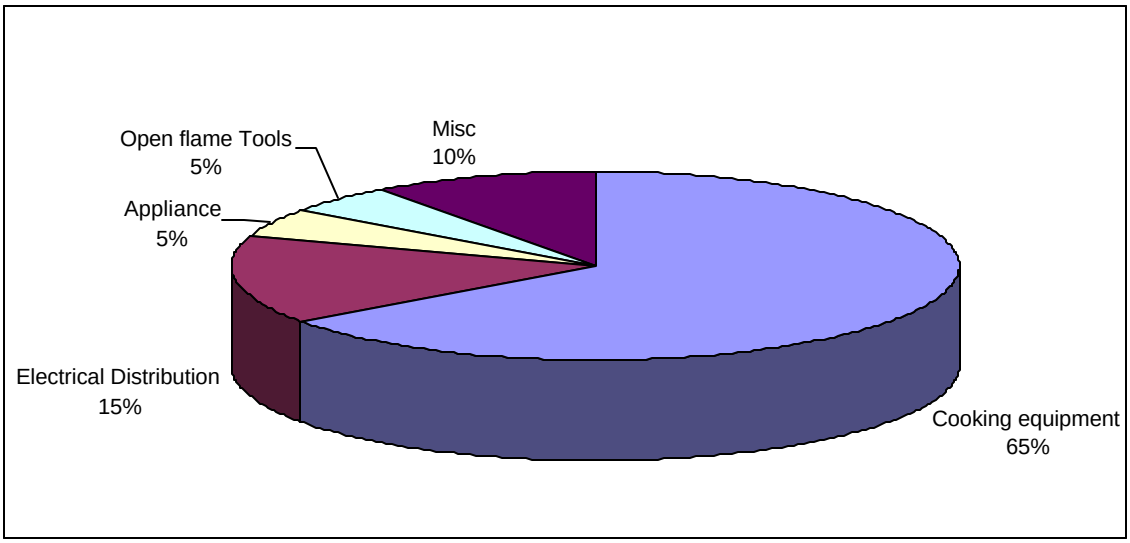
* Other are items not classified by the OFM in the database and miscellaneous are items such as agricultural product, upholstery, structural members, multiple building components – no items shown as miscellaneous individually exceeded 2% in prevalence.

Ignition Source

Stove and range-top burner accounted for 65% of ignition source of injuries, with electrical distribution equipment at 15%, appliance at 5% and open flame tools at 5%. Again, misuse was cited as most predominant cause of range, stove injuries, while failure of electrical equipment and design was the predominant cause for electrical distribution equipment.

Figure 25

Fire Injuries – Ignition Source



5.0. Summary

The data in this document can be summarized as follows;

a) The electrical fatality rate, injuries and injury costs have been on a decline in the last five years. The fatality rate in Ontario is less than that in the United States of America.

b) Electrical fatalities occur more often at the workplace than at home, a trend that has become more obvious in the last three years.

c) There is a high percentage of fatalities in the workplace involving utility infrastructure. The percentage has worsened in the last four years. Employees of utilities are not the victims, but others are. This high percentage of fatality is not attributed to a rise in the number of fatalities involving utility infrastructure. *It is the fact that the number of utility infrastructure fatality has remained relatively the same while the number of other electrical fatalities has declined. This indicates that safety improvements in the number of fatalities involving utility infrastructure is at a status quo while other safety measures in the electrical industry has improved.*

d) Ladders accounted for a more than a quarter of all electrical fatalities and more than 40% of overhead contact fatalities.
e) The number of injuries to industries reflects the number of man-hours worked. Profile of injuries also reflects the type of work performed by the corresponding industries.
f) Electrical injuries represented relatively small numbers of injuries in any sector in any industries and also relatively minor injuries based on cost.
g) Construction electrical injuries were the most severe of all industries. This is based on injury cost and the number of 3rd degree burns. Workers suffered these injuries when contacting wiring and transformers. This can be attributed to the fact that construction personnel are often involved in 'live' operation there is a presence of high voltage. Typically, it involves retrofit of existing plants.
h) Electrical fires occurred mostly in residence. Cooking related activities presented most risk of electrical fires, followed by distribution equipment.
i) Cooking fires were mostly the result of misuse or mishandling of cooking oil or clothing. Distribution equipment fires mostly involved failure of wiring or electrical/extension cords.
j) Cooking and appliances represented almost 80% of electrical fatalities. Most prevalent object first ignited in cooking fatalities was clothing. It has been implied that the majority of these fatalities involved older people. Lack of detailed data prevents confirmation of this deduction.
k) Injury profile of electrical fires is almost identical to the fatality profile.

6.0. Conclusion and Recommendations

6.1. Conclusion

Based on the decline in injury rate, fatalities and property damage, the infrastructure of electrical safety in Ontario appears to be working. Better safety performance than the United States implies that Ontario could have better public awareness and/or better safety infrastructure than the US.

The high percentage of occupational fatalities versus home fatalities can mean two things. One, the provincial electrical safety infrastructure does a good job of protecting general public. It provides built-in protection from electrical danger, regardless people's knowledge of electrical hazards. When the public is unsure, they contract someone to perform the work. Two, electrical safety awareness in the workplace and general public can be improved. Preliminary studies of fatalities imply that victims showed lack of understanding of hazard and essential electrical safety knowledge.

Utility infrastructure accounts for a high percentage of fatalities. More than half of occupational electrical fatalities involved overhead powerline contact. It indicates that the workplace in general requires more education in the danger of powerlines. The utility protects their employees well but it is other workers and general public that continues to be hurt or fatally wounded by powerline contact.

Though the electrical industry in construction has an overall excellent safety record compared to other sectors in the same industry, their work still presented most risks compared to electrical work in other industry sectors. Job process, hazard analysis and communication around energized equipment need to be improved.

There is lack of detail information in accidents, in particular injuries. This resulted in lack of certainty of why the injuries are occurring.

Electrical fires poses the most risks in residential buildings, with cooking being the most risk of all. This is more alarming when 80% of all fire fatalities were the result of cooking. Though description is not provided, the most probable cause of these fatalities are that clothing caught fire, resulting in fatalities.

Existing data provides some direction to ESA as to where the problems lie. However, more detail of the accidents is still required. The problem is more apparent where there is polarization of data. For example, a large number of electrical injuries in manufacturing and service industry points to contact with machinery. Yet, there is lack of information indicating what actually cause the accident (root cause). Was the machine defective, and if so, was it the result of poor maintenance program or lack of training? Was there a fault in design or did the work procedure lack safe practice? All these questions need to be answered so that focus can be directed to the root cause. Otherwise, we would be treating the symptoms rather than dealing with cause of the problem.

6.2 Recommendations

The following is recommended;

- Reduce electrical fatalities by improving awareness, hazard analysis and communication in the workplace, specifically activities around energized powerline and systems. Work with safety partners in the industry, utility owners, MOL, all Safe Workplace Agencies to reduce powerline fatalities.
- Reduce workplace injuries by focusing on detailed collection of data of injuries. Current data can only point to the general direction of where the problems are, but lack of data prevented finding the root cause. Standard reporting that draws vital information to finding the root-cause would solve this problem.

- Reduce cooking related fires that can result in fatalities, injuries and property damage by increasing awareness of cooking hazards and investigating improvements in the product standard.
- Build the ability to acquire selective data to facilitate finding root cause of injuries. A system of data collection and standard reporting must be developed, not just by ESA but partners of ESA in accident prevention. Current data provides direction *where* the problem lies, but doesn't provide adequate information on *what* the problem is.
- Acquire data to prevent home injuries of electrical nature. Aside from fatalities, there are no data on home injuries. ESA is currently working with partners in the industry to gain access of such data and the effort should continue.

References

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5. Office of the Chief Coroner, Electrocution Deaths in the Province of Ontario, 1998.

6. Construction Safety Association of Ontario, 1995-2000 database

7. Construction Safety Association of Ontario, Annual Report from period 1995 to 2000

7. http://www.workcover.com/training/elec-cost.html#indirect, Oct 23, 2001