This is not a peer-reviewed article.

Paper Number: 028017
An ASAE Meeting Presentation

Combine Fire Prevention and Control Summit

M. T. Venem, Graduate Student

University of Minnesota, Department of Biosystems & Agricultural Engineering, 1390 Eckles Avenue, St. Paul, MN 55108, USA

J. M. Shutske, Ph. D., Associate Professor & Extension Agricultural Safety and Health Specialist

University of Minnesota, Department of Biosystems & Agricultural Engineering, 1390 Eckles Avenue, St. Paul, MN 55108, USA

Written for presentation at the
2002 ASAE Annual International Meeting / CIGR XVth World Congress
Sponsored by ASAE and CIGR
Hyatt Regency Chicago
Chicago, Illinois, USA
July 28-July 31, 2002

Abstract. *Much work was done in the 1970's and 1980's related to self-propelled grain combine fires, their causes, and associated costs. To compliment this information, National Fire Incident Reporting System (NFIRS) data were analyzed to determine if trends and rates have fluctuated since past research.*

Results from 1984 – 1995 and 1997 NFIRS records from all reported states yielded 8,307 combine fires in 38 states. The 1998 – 2000 data from 5 of the top 10 states with combine fire occurrences were also analyzed, providing an additional 620 cases. This work summarizes information related to the time of day, day of the week, month, and year the fire occurred. Summary statistics of the ignition factor that allowed the fire to start, location of fire origin, composition of the material first ignited, and estimated total dollar loss for the combine fires are also identified within this study.

Keywords. Fires, Combine, Machinery Fires, Fire Prevention, Safety

Introduction

Fires on grain combines have been documented as early as 1856, but the problem was not addressed in technical literature until Heston (1973) analyzed 513 tractor and combine fires. In 1982, the National Association of Mutual Insurance Companies (NAMIC) conducted a study of 785 combine fires and 2,160 tractor fires (Reeves, 1982). Following this research, Moore (1987) analyzed 89 combine fires for insights into patterns of makes and models involved in fires. From this early research, it was established that combine fires occur less frequently than tractor fires, but the magnitude of the loss for combines is much larger.

To accompany earlier research; on-site investigations, fire marshal reports, fire victim surveys, and NFIRS data that described 4,092 combine and tractor fires occurring from 1982 to 1986 were analyzed (Shutske et al., 1990). The data documented the magnitude of fire loss on combines and tractors, described fire causes and characteristics, and developed fire prevention recommendations for the designer/manufacturer and end-user. It was further established that the majority of combine fires occurred in the early afternoon, with the most fires occurring in the engine compartment. The type of flammable material first involved in agricultural machinery fires was primarily crop residue, engine fuel, and hydraulic fluid. Further analysis demonstrated that 90% of those surveyed self-reported that they followed the routine maintenance schedule recommended in the operator's manual based on self-reporting by 50 individuals who had experienced a combine fire.

While past research has shown that fires on agricultural equipment were at one time a serious problem (Shutske et al., 1987), no recent research has been performed to determine if combine fires are still a problem. Additionally, no previous work has explored the long term rates and trends associated with combine fires to determine changes in the location of the fire or if different materials were involved in or contributed to the fire.

This work analyzes 8,307 combine fires from the records of NFIRS data from 1984 through 1995 and 1997 for all states that used the NFIRS system, termed the "Main Dataset", to provide insight into the long term trends and rates associated with combine fires. Due to the inability to acquire data from 1996 in a timely manner, it was not included. It is believed that the absence of 1996 data will have a minimal effect on the overall outcome of the study because of the large size of the data set that was available. Following the analysis of data from 1984 to 1997, the state fire marshals' offices in the ten states with the highest average of combine fires reported were contacted to request more recent data. The state offices generally have more timely data due to a three to four year lag time between the development of local data sets and when the data becomes publicly available as part of the national data set. Of the top ten states having the most combine fires, five states responded in a timely manner and are included in the study. These five states, termed the "Midwest Subset", account for an average of 32.6% of the reported cases and are representative of the Main Dataset based on a comparison between the Main Dataset and the Midwest Subset for the years 1984 – 1997.

This study is the largest of its kind to strictly involve combine fires, and the first public document to analyze the long-term rates and trends of fire data for agricultural equipment.

Safety Emphasis

Shutske & Field (1988) noted that, based on NFIRS data, two out of every 100 agricultural machinery fires resulted in a personal injury, and one in every 1000 fires resulted in a death. The work described in this paper benefits both the end user and the designer/manufacturer by providing information as to when a combine fire occurs or where fires do occur on combines.

The time of day, day of the week, and month the fire occurred offer valuable insights into what temporal conditions are present when fires occur and what type of maintenance schedule manufacturers should recommend and end users should follow. The ignition factor, area of fire origin, equipment involved in the ignition, and type of material ignited allow specific information as to what material caused the fire to begin, what material first started on fire, and also the location on the machine where the fire occurred. With this work showing that an average of 639 self-propelled grain combine fires were reported each year, with an average loss of $15,182 per fire, we feel that there is a need to create a safety standard specific to the prevention of fires on self-propelled grain combines. A safety standard could help to reduce the frequency and magnitude of combine fires, and ultimately reduce the resulting injuries and deaths. An engineering standard could also specify the types of fire control and suppression hardware to be used with every type of self-propelled machine including handheld extinguishers, detectors, and fixed suppression equipment.

Methods

A total of 32,132 Mobile Property Type 65 (tractor, harvester, picker) cases from states participating in the U.S. Fire Administration's (USFA) NFIRS program were analyzed for the years 1984 through 1995 and 1997 using SPSS 10 statistical analysis software. A pictorial representation of the states participating in the NFIRS is located in Appendix A. These data were sorted initially with queries to extract cases that involved a combine. The remaining data were manually sorted to remove all cases that could not be identified as a combine fire.

Manual sorting was performed by creating a master list of makes and models of combines and removing cases that did not correspond to the list. The master list was compiled from the 2002 Hot Line Farm Equipment Guide created by the Heartland Ag-Business Group. This source, while not encompassing all makes and models of equipment, was assumed to contain at least 95% of the combines represented in the NFIRS data. Any model identification that was also given to another type of machine or implement was further removed if it could not be specifically identified as a combine. It was further assumed that local fire departments would likely label a combine as a tractor, but not vice versa, due to combines being a form of specialty equipment while tractors are used in several industries and thought to be more common and recognized, so cases labeled as a combine were saved. This data set yielded 8,307 cases believed to be combines.

Frequency analysis on the state where the fire occurred was done to determine the ranking of states by number of total combine fires that occurred. State fire marshals from the ten states with the highest reported combine fires were contacted to request Mobile Property Type 65 data from 1998 through their most recent records, because publication of the nationally compiled NFIRS dataset has an approximate four-year lag before they are made publicly available by the federal government on data tapes or CD-ROM. Five of these states, OH, KS, MN, NE, MI, termed the Midwest Subset, ranked 3, 5, 6, 7, 9 respectively, based on the total number of fires that had occurred, responded in a timely manner. OH, KS, MN, and MI provided data from 1998 through 2000, while NE only provided data from 1998 and 1999. The cases from 1998 through 2000 were sorted following the techniques used for the Main Dataset, yielding 620 additional combine fires.

The cases assumed to be combines from 1984 through 2000 were combined and further analyzed in regard to the time of day, day of the week, month, and year the fire occurred; and the ignition factor, area of fire origin, equipment involved in the ignition, type of material ignited, and estimated total dollar loss. This analysis was completed using Microsoft Excel and SPSS 10 software programs.

Results and Discussion

Time Fire Occurred

The time of day at which the fire occurred for the Midwest Subset is shown in Figure 1, with all years lumped into an average value. Yearly data for the Main Dataset and the Midwest Subset are included in Appendix B. The time of day fires occurred appears to follow a normal distribution, with the highest percentage of fires occurring at mid-afternoon. It should also be noted that 78.2% of fires occurred between noon and 8:00 PM, and nearly one-half (48.5%) of fires occurred between 2:00 PM and 6:00 PM. This high percentage of fires can likely be attributed, at least in part, to more total hours of operation in the afternoon and drier field conditions due to higher temperatures and evaporation of morning dew. Farmers potentially cleaning machines each morning before harvesting could also impact the distribution, but further research is needed to fully understand combine cleaning habits. Nevertheless, a potential reduction in fires could be achieved by recommending that combines be maintained and cleaned twice a day at approximately noon and mid-afternoon or investigating additional means to minimize or eliminate the accumulation of crop residue near ignition sources during operation.

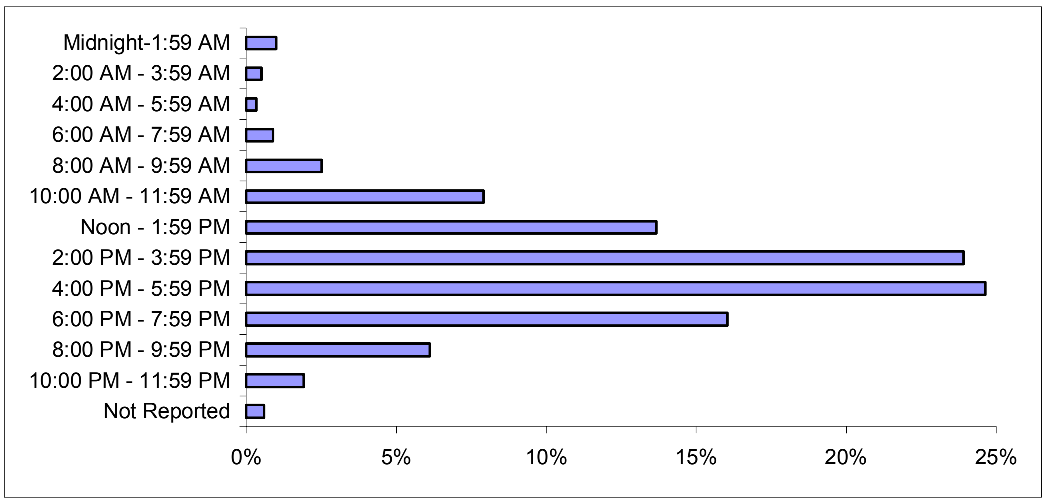


Figure 1. Time of day fires occurred from 1984 and 2000 for the Midwest Subset.

The day of the week on which fires occurred for the Midwest Subset separated into four-year groupings from 1984 – 2000 is shown in Figure 2, with individual year data for the Main Dataset and the Midwest Subset in Appendix C. Data for 1984 – 1987 suggest that fires occurred at approximately the same rate from Monday through Friday with approximately 50% relative decrease in fires on Sunday. Comparison of the data groups 1988 – 1991, 1992 – 1995, and 1997 – 2000 show a decreasing trend in the amount of fires that occur on Monday, Tuesday, and Wednesday, and an increase in the amount of fires that occurred on Thursday, Friday, and Saturday. The increase in fires in the latter part of the week could be attributed, in part, to a trend of accumulation of crop residue and/or decreased cleaning practices as the week progresses. It should be noted that the sample size for 1984 – 1997 data is over 4 times larger than that of 1998 – 2000 data, potentially contributing to the trend shift. Additional research is needed to determine the true cause of the increase in trends as the week progresses from Sunday through Saturday. Both data sets demonstrate a decrease in fires on Sunday, possibly attributed to decreased combine use due to attending religious services or limited weekend grain elevator hours.

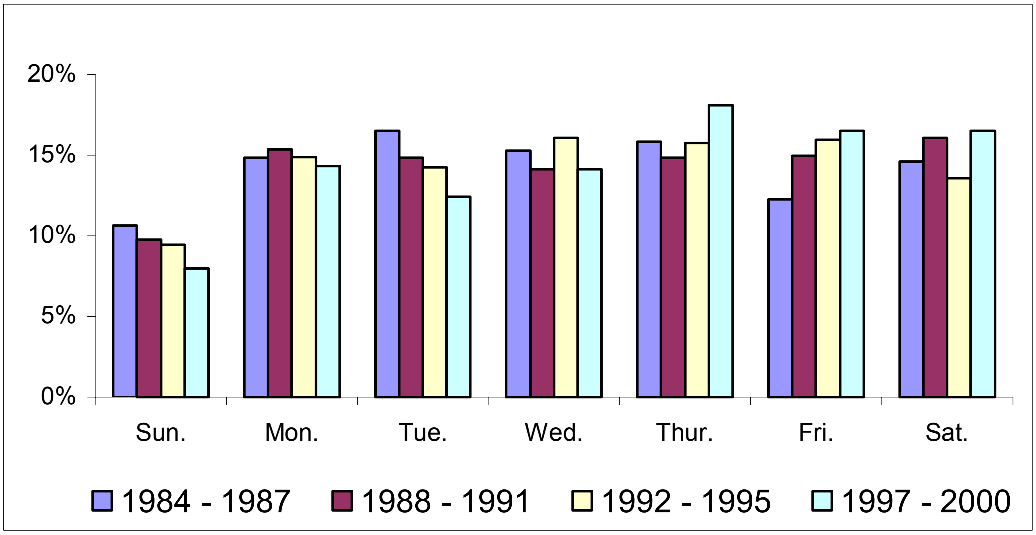


Figure 2. Day of the week fire occurred for the Midwest Subset.

The Midwest Subset is a good representation the Main Dataset as to the month the fire occurred and was used to compare trends between the 1984 – 1987, 1988 – 1991, 1992 – 1995 and 1997 – 2000 data groups (Figure 3). Source data for the Main Dataset and the Midwest Subset is located in Appendix D. As expected, and also reported in Shutske & Field (1988), the majority, 67.9%, of fires occurred during the fall harvesting period (late September-November) and 11.4% during wheat harvest (July). In order to accurately compare the rate of combine fires that occur during the two harvesting periods, additional data that is normalized to the hours of exposure for each season is needed, providing insight as to whether the fall or wheat harvesting periods have a higher fire incidence on an hourly rate. This exposure data would also provide additional insights into the temporal aspects and characteristics of fires that were previously described. In comparing the 1984 – 1987 and 1997 – 2000 data groups, a large increase of fires in September and October, 15.6% and 16.2% respectively, and a decrease of fires in June and November of 9.0% and 11.2% respectively, are present, but further research is necessary to explain the shift from the wheat harvest to the fall harvest.

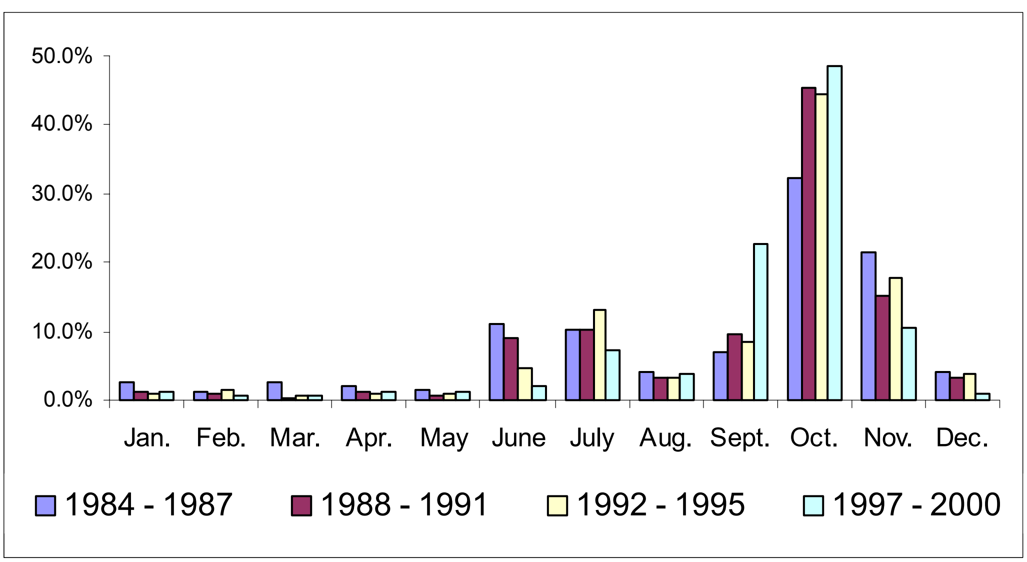


Figure 3. The month when the fire occurred for the Midwest Subset.

Figure 4 summarizes the frequency of reported combine fires that occurred each year from 1984 through 2000, with a tabular form of the data located in Appendix E. An average of 639 combine fires occurred each year from 1984 through 1997 amongst states using the NFIRS system. There appears to be a cyclical trend of fires increasing over a three to four year period, and then decreasing substantially, but the cause of this cyclical trend is unexplained. A possible explanation of this trend could be weather related, such as the summer drought of 1988 potentially causing a reduction in total hours of machine operation, thus reducing the potential for fire, but more research is needed to determine the cause. Again, exposure data that would provide information on total hours of machine usage would be helpful to determine what is causing the appearance of a cyclical trend.

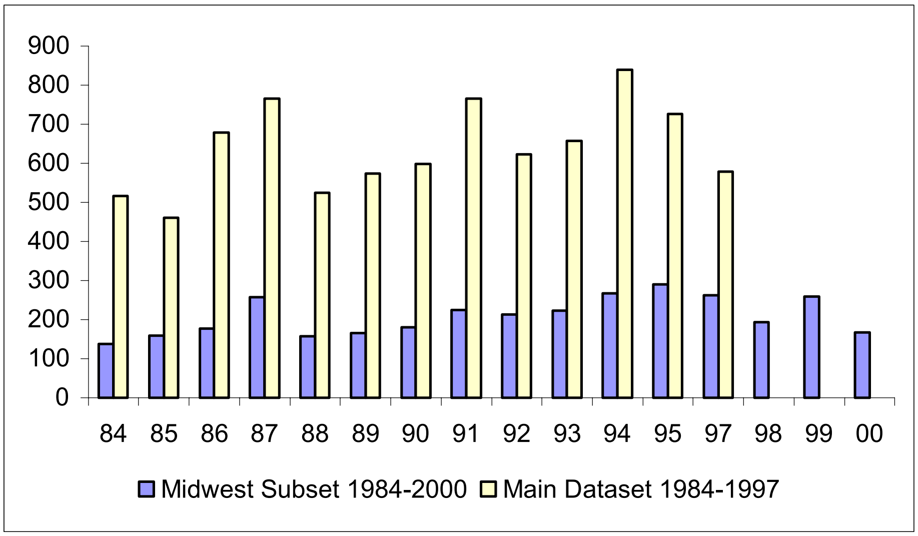


Figure 4. Year the fire occurred for the Midwest Subset and the Main Dataset.

Factor Involved in the Ignition

Figure 5 shows the ignition factor that allowed the fire to start as an average for 1984 through 2000 data for the Midwest Subset. The full data set with the ignition factor for each year is located in Appendix F. It must be noted that this data is subjective based on a determination by the case reporter, often a local fire service volunteer who is left with the task of determining how to report the ignition factor. Almost 50% of the fires were caused by mechanical or electrical failures, suggesting that research into these two types of ignition factors would greatly reduce combine fires.

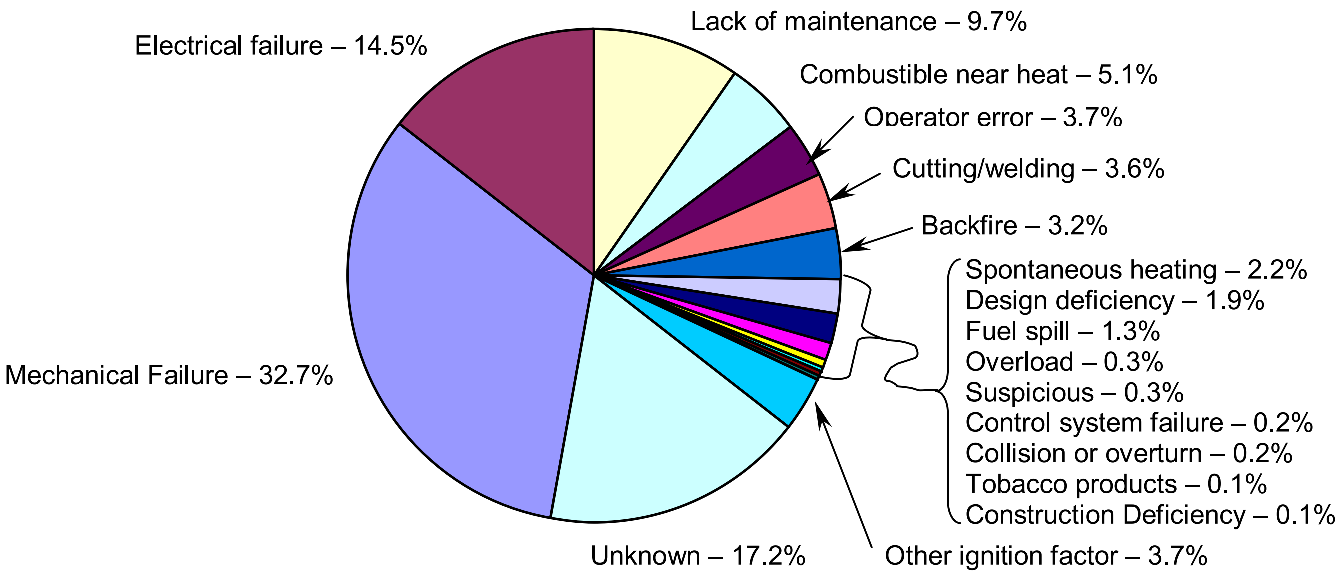


Figure 5. The ignition factor from the Midwest Subset 1984 – 2000.

Location of Fire Origin

The location of fire origin from the Midwest Subset 1984 – 2000 is located in Figure 6, with yearly information for both the Main Dataset and Midwest Subset located in Appendix G. The majority of fires (76.7%) originated in the engine area, which suggests additional design work is needed to prevent fires from occurring in this area. During recording, field and shop locations were listed as the location of fire origin, accounting for 263 and 42 cases respectively within the Midwest Subset and 692 and 40 cases respectively within the Main Dataset. These cases were removed from Figure 6 and Appendix G because they were believed to be incorrectly recorded in the same fashion noted by Shutske & Field (1988), where the geographic location at which the fire occurred was recorded rather than the location on the combine.

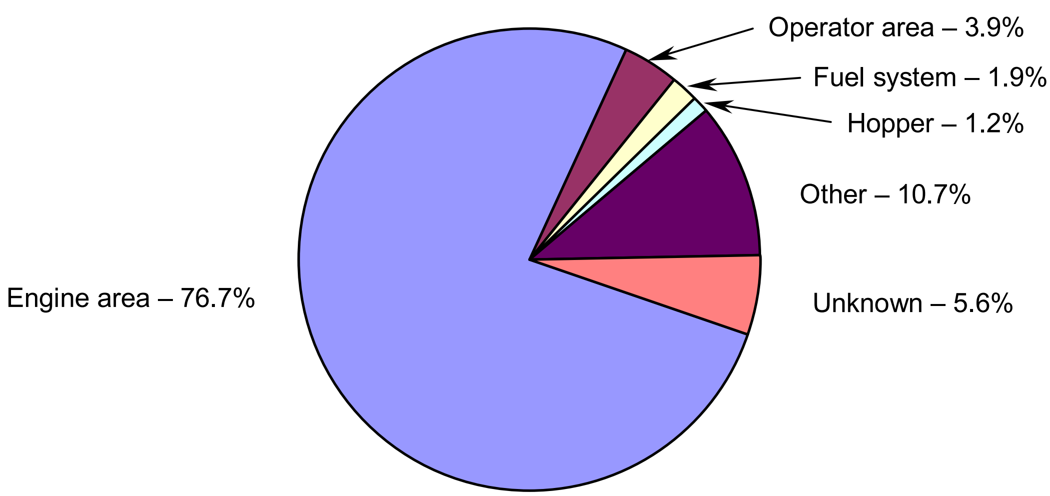


Figure 6. Location of fire origin for the Midwest Subset 1984 – 2000.

Material First Ignited

The composition of the material first ignited for the Midwest Subset is shown in Figure 7, with a yearly analysis for both the Midwest Subset and the Main Dataset located in Appendix H. Organic materials were reported most frequently, agreeing with the research performed by Shutske & Field (1988). Within this referenced work, NFIRS data from all type 65 cases and data from 50 Indiana combine fires were analyzed. There was some deviation between the two data sets, but results shown in Figure 7 closely match the Indiana data, further validating fully separated NFIRS combine data.

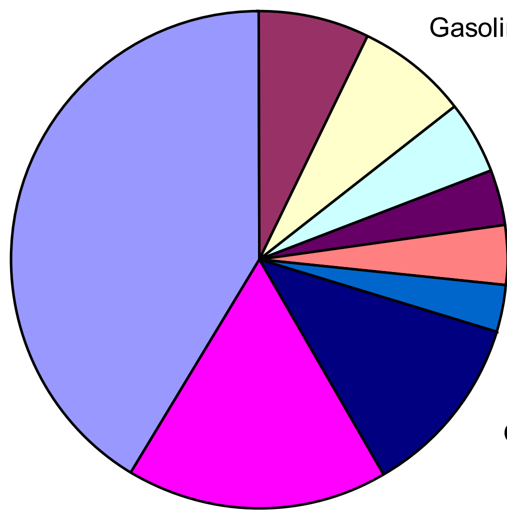


Figure 7. The material first ignited in the combine fire for the Midwest Subset 1984 - 2000.

Losses Resulting from Reported Fires

Figure 8 shows the average loss per combine fire after correcting for inflation to June of 2002, with additional loss calculations located in Appendix I. The correction for inflation was performed using the CPI index provided by the Bureau of Labor Statistics. From 1984 – 1997, $94,748,050 in property damage losses were reported to the NFIRS from the Main Dataset. This does not include 1996 data, additional combine fire cases that occurred but could not be identified, fires not reported, and other losses associated with downtime, injuries and deaths, or the use of fire department resources. This is an average of $15,182 per combine fire. From 1998 – 2000, $3,451,183 in losses were reported from the Midwest Subset alone, averaging $13,860 per fire. A possible explanation for the difference in average loss per fire is assumed to be due to the valid percent of cases in which a dollar loss was actually reported at the time of the fire investigation. The 1984 – 1997 data averaged a valid loss report rate of 75.5%, while data from 1998 – 2000 averaged 39.8%, reducing the sample size and confidence in the 1998 – 2000 data. This reduction in valid loss report rate, coupled with the reduced sample size for 1998 – 2000 data, suggest that $15,182 is a better approximation of the loss per combine fire because the data is more complete. Another potential explanation that was not explored further is that Midwestern combine fires might cause less damage or might be deemed by the investigators in those states as less expensive to repair.

Assuming the Midwest Subset comprises, on the average, 32.6% of reported fires that occur throughout the nation, approximately $10,586,451 in losses occurred nationally among those fires reported through NFIRS. Looking at the trend from 1984 – 2000, the average reported loss from a combine fire seems relatively constant. Possible explanation of this is that the majority of fires do occur on older equipment, valued at a similar level throughout time, or that the magnitude of fires is, on the average, constant, while the value of combines is increasing.

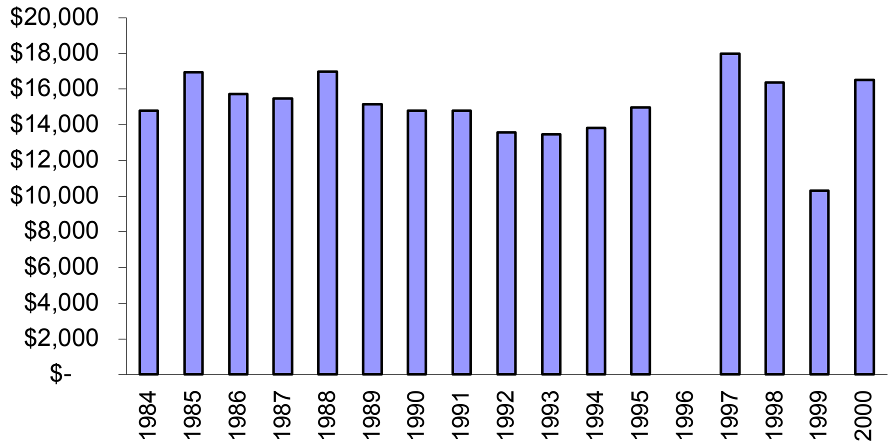


Figure 8. Average loss from 1984 – 2000 adjusted for inflation.

Conclusions

8,307 combine fires from 1984 – 1997 for all states using the NFIRS system and 620 combine fires from 1998 – 2000 for the Midwest Subset were analyzed to determine the time of day, day of week, month, and year the fire occurred; as well as the ignition factor, area of fire origin, type of material ignited, and estimated total dollar loss. Condensed results of this study are listed below.

- 78.2% of combine fires occur between noon and 8:00 PM, 48.5% occur between 2:00 PM and 6:00 PM.
- The majority of fires occur during the week, with the fewest on Sunday. 1984 – 1997 data suggests a higher rate of fires in the middle of the week with 1998 – 2000 data suggesting a shift to the end of the week.
- 67.9%, of fires occurred during the fall harvesting period (late September-November) with a decrease in the frequency of fires during wheat harvest and an increase in fires during the fall harvest from 1984 to 2000.
- 639 reported combine fires occur, on the average, each year in those states that report to the NFIRS.
- 47.2% of combine fires reported mechanical or electrical failure as the ignition factor starting the fire.
- 76.7% of combine fires originate in the engine area
- 41.3% of combine fires have organic material as the type of flammable material first involved in the fire.
- From 1984 – 1997, $94,748,050 in estimated losses from combine fires were reported, averaging $15,182 per fire.

Using this research as a starting point, further discussion is needed to determine if the loss magnitude and rate of self-propelled grain combine fires are acceptable by all stakeholders involved. This discussion should include manufacturers, the insurance industry, dealers, operators, and other parties who have knowledge of self-propelled grain combines or fire detection, prevention, and suppression.

If discussion determines that fires are an issue, a safety standard should be developed that addresses fire prevention from the design and manufacturing perspective, as well as the operator maintenance perspective. Similar standard information is needed in relation to fire suppression and control, specifically regarding the size, type, location, and the number of fire extinguishers needed, along with referrals to appropriate fire control standards.

Additional exposure data would also be helpful to further examine various trends that were observed in this analysis. It would be beneficial to know within a given 24-hour period what the hours of field exposure for combines are. It would also be helpful to know how much exposure varies by day of the week and by month within given geographic locations. Ultimately, exposure data, while difficult and expensive to collect, would yield much richer information related to fire risk factors. However, the descriptive information that has been presented here does provide useful information and a snapshot that shows the magnitude and general characteristics of the combine fire problem.

Additionally, with the increased application of machinery performance sensors on combines, and machinery in general, fire or high temperature sensors seem to be a feasible addition, and a means of detecting when a fire occurs. Previous testing by Shutske et al. (1994) found that early fire detection often allowed a fire to be extinguished with typical handheld dry chemical extinguishers, increasing the operator's safety and ability to extinguish the fire. Later detection allows the fire to more fully develop and heat surrounding components, which serve as re-ignition points, often making fire suppression with handheld equipment difficult or impossible.

Further research is also needed to determine:

1. Maintenance habits performed by the combine operator.
2. Means of minimizing or eliminating the accumulation of crop residue near ignition sources.
3. The reasoning behind the shift towards fires at the end of the week.
4. Why fires are occurring earlier in the fall harvest season?
5. If more fires occur during the fall harvesting period per hour of exposure.
6. Why there is a cyclical trend in the year combine fires occur?
7. How to reduce mechanical and electrical failures?

References

Bureau of Labor Statistics. 2002. CPI Inflation Calculator. U.S. Department of Labor. Available at: http://data.bls.gov/cgi-bin/cpicalc.pl. Accessed on 25 July 2002.

Heartland Ag-Business Group. 2002 *Hot Line Farm Equipment Guide: Quick Reference Guide.* 21st ed. Fort Dodge, Iowa: Author.

Heston, R.E. 1973. Farm Machinery fires…How big a problem? ASAE Paper No. 73-150. St. Joseph, Mich.: ASAE.

Moore, G.H. 1987. Report of survey into fires involving agricultural vehicles. Special report compiled by the Lincolnshire Fire Brigade, Lincolnshire, England.

Reeves, R.H. 1982. Theft and fire survey – Self-propelled farm machinery. Special bulletin, National Association of Mutual Insurance Companies, Indianapolis, IN.

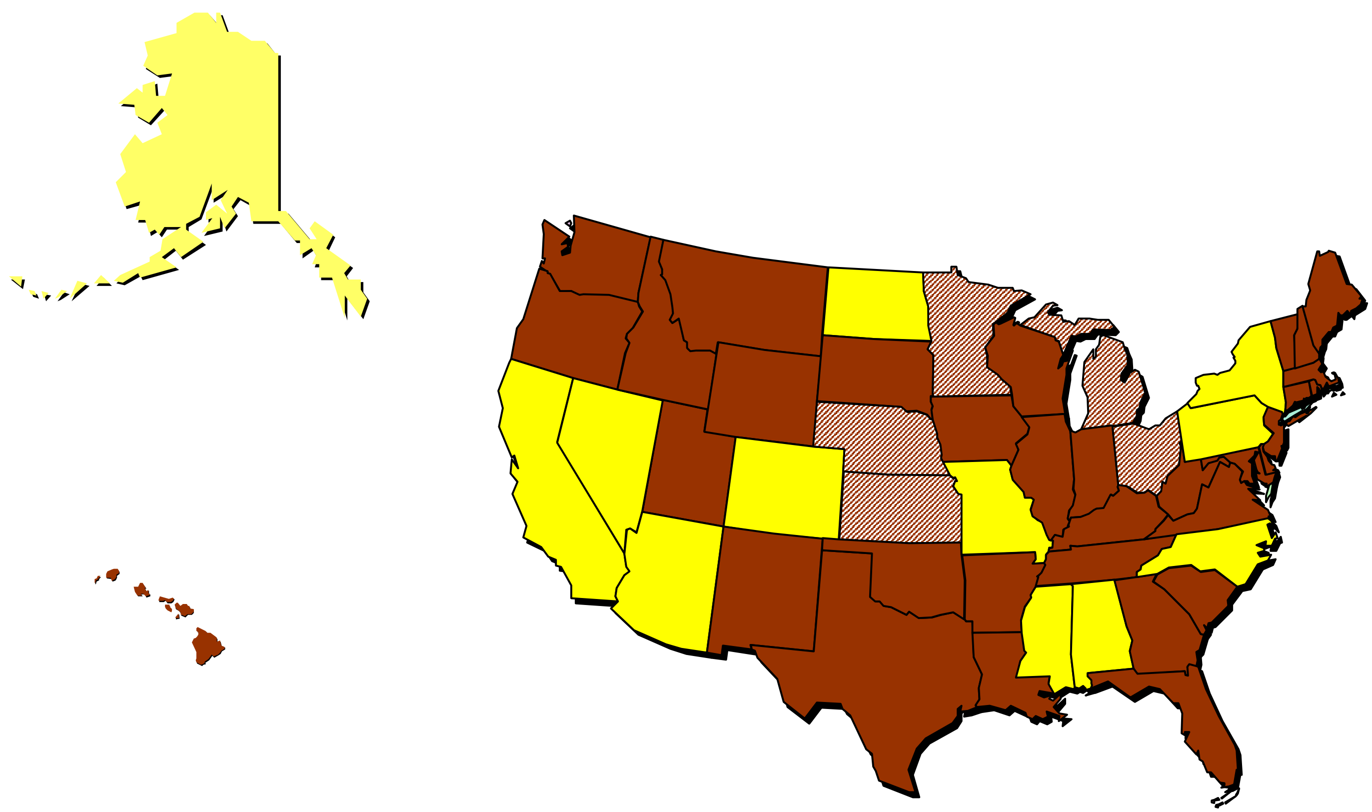
Shutske, J.M., and Field, W.E., 1988. An integrated loss control strategy for grain combine fires. ASAE Paper No. 885518. St. Joseph, Mich.: ASAE.

Shutske, J.M., Field, W.E., and Chaplin, J. 1994. Grain combine fires: a loss reduction approach. Applied Eng. Agric. 10(2): 175-182.

Shutske, J.M., Field, W.E., and Huffman, D. 1987. The installation and testing of halon fire suppression system for self-propelled grain combines. ASAE Paper No. 875006. St. Joseph, Mich.: ASAE.

Shutske, J.M., Field, W.E., Gaultney, L.D., and Parsons, S.D. 1990 Agricultural machinery fire losses: a preventative approach. Applied Eng. Agric. 6(5): 575-581.

Appendix A: States reporting to the NFIRS



States comprising the Main Dataset   States comprising the Midwest Subset   States not reporting to the NFIRS

Appendix B: Time of day when the fire was reported

Time of the day when the fire occurred for the Main Dataset 1984-1997

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Midwest subset (84-97)	All states reported (84-97)
Midnight-1:59 AM	2	6	1	4	2	4	4	3	4	2	2	7	na	3	16	44
2:00 AM - 3:59 AM	5	2	5	2	1	2	0	5	6	2	5	5	na	4	10	44
4:00 AM - 5:59 AM	5	1	4	4	0	1	3	1	1	3	2	5	na	5	9	35
6:00 AM - 7:59 AM	6	4	8	8	2	5	9	12	6	8	7	8	na	5	24	88
8:00 AM - 9:59 AM	24	17	27	18	10	14	20	20	17	27	21	14	na	15	74	244
10:00 AM - 11:59 AM	71	43	58	58	62	41	68	73	70	48	73	60	na	49	220	774
Noon - 1:59 PM	62	63	110	106	77	100	105	116	87	97	130	105	na	84	370	1242
2:00 PM - 3:59 PM	122	109	161	177	137	152	153	197	141	164	183	193	na	150	643	2039
4:00 PM - 5:59 PM	108	97	139	208	130	146	137	178	145	165	215	172	na	143	666	1983
6:00 PM - 7:59 PM	72	81	104	126	85	76	54	103	84	106	138	91	na	72	447	1192
8:00 PM - 9:59 PM	25	21	52	41	15	25	32	49	51	18	44	47	na	33	168	453
10:00 PM - 11:59 PM	10	16	9	13	4	7	14	9	9	13	17	13	na	11	55	145
Not Reported	4	1	1	0	0	0	0	0	2	4	2	6	na	4	16	24
Total	516	461	679	765	525	573	599	766	623	657	839	726	na	578	2718	8307

Time of the day when the fire occurred for the Midwest Subset 1984-2000

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Midwest subset (84-00)
Midnight-1:59 AM	1	2	1	1	2	1	0	1	2	0	1	3	na	1	3	9	5	33
2:00 AM - 3:59 AM	1	1	0	1	1	1	0	0	0	1	1	2	na	1	1	3	3	17
4:00 AM - 5:59 AM	2	0	0	1	0	0	0	0	0	0	0	3	na	3	0	2	0	11
6:00 AM - 7:59 AM	2	0	3	2	1	2	1	4	0	0	0	4	na	5	3	1	2	30
8:00 AM - 9:59 AM	8	5	6	5	2	7	7	3	5	4	7	4	na	11	4	1	5	84
10:00 AM - 11:59 AM	20	10	14	11	16	12	15	18	25	14	19	20	na	26	17	17	10	264
Noon - 1:59 PM	11	24	22	33	18	41	24	30	27	26	34	43	na	37	23	37	26	456
2:00 PM - 3:59 PM	34	25	37	67	43	38	41	56	53	58	59	68	na	64	46	70	39	798
4:00 PM - 5:59 PM	28	36	40	67	41	32	47	56	47	59	77	71	na	65	55	64	37	822
6:00 PM - 7:59 PM	19	36	35	49	27	24	27	39	34	42	47	39	na	29	28	39	21	535
8:00 PM - 9:59 PM	9	10	18	14	5	8	12	15	16	10	14	21	na	16	9	14	13	204
10:00 PM - 11:59 PM	1	10	1	6	2	0	6	2	5	6	7	7	na	2	4	3	2	64
Not Reported	2	1	1	0	0	0	0	0	0	3	2	5	na	2	0	0	4	20
Total	138	160	178	257	158	166	180	224	214	223	268	290	na	262	193	260	167	3338

Appendix C: The day of the week when the fire occurred

The day of the week when the fire occurred for the Main Dataset 1984-1997

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Midwest Subset (84-97)	Main Dataset (84-97)
Sunday	35	31	64	78	40	45	45	71	66	63	86	70	na	56	267	750
Monday	59	82	112	117	92	86	90	98	99	91	123	112	na	101	412	1262
Tuesday	89	73	126	104	88	79	99	121	76	106	125	118	na	72	404	1276
Wednesday	107	85	102	95	80	87	81	122	94	111	145	132	na	94	423	1335
Thursday	65	82	94	154	70	88	102	124	91	114	128	100	na	83	419	1295
Friday	79	64	100	104	77	88	93	123	105	89	134	85	na	83	396	1224
Saturday	82	44	81	113	78	100	89	107	92	83	98	109	na	89	397	1165
Total	516	461	679	765	525	573	599	766	623	657	839	726	na	578	2718	8307

The day of the week when the fire occurred for the Midwest Subset 1984-2000

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Midwest Subset (84-00)
Sunday	12	11	19	36	13	10	22	26	19	21	23	31	na	24	12	28	6	313
Monday	12	24	29	44	35	26	26	25	33	32	37	46	na	43	33	28	22	495
Tuesday	32	24	31	34	26	18	32	32	28	35	36	43	na	33	27	31	18	480
Wednesday	25	31	23	33	19	26	19	39	25	35	42	58	na	48	21	34	21	499
Thursday	17	32	25	42	25	25	24	34	36	36	41	44	na	38	28	61	32	540
Friday	17	20	25	28	18	26	33	32	37	32	51	39	na	38	41	36	30	503
Saturday	23	18	26	40	22	35	24	36	36	32	38	29	na	38	31	42	34	504
Total	138	160	178	257	158	166	180	224	214	223	268	290	na	262	193	260	163*	3334

*** Four cases with day of the week not reported**

The day of the week when the fire occurred for the Midwest Subset separated into four year data groups

	1984-1987	1988-1991	1992-1995	1997-2000
Sunday	78	71	94	70
Monday	109	112	148	126
Tuesday	121	108	142	109
Wednesday	112	103	160	124
Thursday	116	108	157	159
Friday	90	109	159	145
Saturday	107	117	135	145
Total	733	728	995	878

Appendix D: The month when the fire occurred

The month when the fire occurred for the Main Dataset 1984-1997

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Midwest Subset (84-97)	Main Dataset (84-97)
January	4	10	36	13	2	4	2	4	3	15	5	10	na	11	46	119
February	0	2	1	8	5	2	2	2	6	13	5	9	na	5	32	60
March	4	6	16	7	3	2	3	6	5	7	5	2	na	8	29	74
April	7	3	32	12	5	4	3	5	3	7	5	7	na	19	37	112
May	7	4	13	6	9	1	5	8	6	11	6	5	na	9	28	90
June	35	30	43	42	56	20	27	57	38	19	53	22	na	18	203	460
July	35	58	42	48	60	39	74	42	59	54	50	93	na	44	311	698
August	28	25	36	24	20	28	45	39	43	32	32	25	na	28	91	405
September	38	26	40	138	66	75	50	131	39	44	85	81	na	94	238	907
October	143	169	218	397	230	307	267	397	261	291	426	391	na	255	1127	3752
November	193	97	157	62	49	81	110	62	107	147	156	68	na	76	480	1365
December	22	31	45	8	20	10	11	13	53	17	11	13	na	11	96	265
Total	516	461	679	765	525	573	599	766	623	657	839	726	na	578	2718	8307

The month when the fire occurred for the Midwest Subset 1984-2000

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Midwest Subset (84-00)
January	3	3	9	5	2	2	1	3	2	3	3	2	na	8	0	1	0	47
February	0	1	1	6	3	1	1	2	3	7	1	4	na	2	2	0	0	34
March	4	3	8	4	0	0	1	1	0	3	2	0	na	3	1	2	0	32
April	4	1	2	7	3	3	2	0	1	2	2	3	na	7	2	1	1	41
May	0	3	6	2	4	0	0	0	0	5	2	2	na	4	3	1	1	33
June	21	19	18	23	26	4	14	22	10	4	26	7	na	9	3	2	4	212
July	20	29	9	16	19	8	36	11	23	26	18	64	na	32	12	13	8	344
August	8	6	7	8	2	6	8	8	12	7	7	5	na	7	10	9	6	116
September	4	5	4	39	12	17	8	33	11	10	35	28	na	32	56	66	45	405
October	22	48	53	114	50	85	69	127	91	100	116	136	na	116	82	146	82	1437
November	44	28	53	33	23	34	36	17	40	49	52	34	na	37	20	19	15	534
December	8	14	8	0	14	6	4	0	21	7	4	5	na	5	2	0	1	99
Total	138	160	178	257	158	166	180	224	214	223	268	290	na	262	193	260	163*	3334

*** Four cases with the month not reported**

The month when the fire occurred for the Midwest Subset separated into four year data groups

	1984-1987	1988-1991	1992-1995	1997-2000
January	20	8	10	9
February	8	7	15	4
March	19	2	5	6
April	14	8	8	11
May	11	4	9	9
June	81	66	47	18
July	74	74	131	65
August	29	24	31	32
September	52	70	84	199
October	237	331	443	426
November	158	110	175	91
December	30	24	37	8
Total	733	728	995	715

Appendix E: The year when the fire occurred

	Main Dataset 84-97	Midwest Subset 84-00
84	516	138
85	461	160
86	679	178
87	765	257
88	525	158
89	573	166
90	599	180
91	766	224
92	623	214
93	657	223
94	839	268
95	726	290
97	578	262
98	na	193
99	na	260
00	na	167
Total	8307	3338

Appendix F: The ignition factor that allowed the fire to start

Ignition factor for the Main Dataset 1984-1997

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Midwest subset (84-97)	Main Dataset (84-97)
Mechanical failure	135	117	193	188	158	152	195	249	199	184	292	223	na	179	889	2464
Electrical failure	81	77	102	112	96	91	103	104	85	109	109	109	na	82	418	1260
Lack of maintenance	48	43	66	71	42	57	58	67	56	70	86	60	na	52	252	776
Combustible near heat source	45	34	50	75	45	54	43	56	51	51	41	64	na	36	144	645
Operational error	24	22	21	21	13	17	10	20	22	14	15	23	na	18	91	240
Cutting or welding	16	29	23	19	15	14	22	24	19	27	29	19	na	23	100	279
Backfire	22	21	36	42	18	18	12	36	15	14	24	13	na	9	94	280
Spontaneous heating	14	10	21	35	11	22	13	34	5	17	36	24	na	18	64	260
Design deficiency	7	1	10	13	4	2	9	15	7	7	7	8	na	7	55	97
Fuel spill	8	8	14	14	5	8	12	5	11	11	9	11	na	1	43	117
Overload	8	4	5	3	5	3	1	1	0	2	5	0	na	0	10	37
Suspicious	4	1	3	2	2	1	3	1	0	2	4	3	na	3	9	29
Control system failure	0	0	3	0	2	0	1	2	0	1	3	0	na	1	8	13
Collision or overturn	0	1	1	1	1	0	4	0	1	0	0	1	na	1	5	11
Tobacco products	1	0	0	1	1	0	1	2	0	1	0	0	na	0	4	7
Construction deficiency	1	2	1	0	0	0	0	0	0	0	1	0	na	0	2	5
Other ignition factor	20	19	24	25	24	17	31	24	29	34	45	28	na	31	106	351
Unknown	82	72	106	143	83	117	81	126	123	113	133	140	na	117	424	1436
Total	381	344	486	577	367	421	404	517	424	473	547	503	na	399	1829	8307

Ignition factor for the Midwest Subset 1984-2000

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Midwest Subset (84-00)
Mechanical Failure	52	47	69	64	56	40	65	70	76	71	101	89	na	89	55	99	48	1091
Electrical failure	19	31	16	32	29	27	31	26	30	39	40	58	na	40	33	21	10	482
Lack of maintenance	10	14	20	21	7	16	15	20	27	25	27	31	na	19	28	23	21	324
Combustible near heat	5	10	4	26	6	17	12	12	8	16	9	11	na	8	6	11	10	171
Operational error	5	10	9	11	4	6	1	9	5	5	5	7	na	14	10	8	15	124
Cutting/welding	3	9	5	10	4	6	6	10	6	14	8	10	na	9	6	11	2	119
Backfire	2	7	10	13	7	9	4	11	6	3	11	7	na	4	2	8	4	108
Spontaneous heating	1	2	1	20	3	3	5	7	0	6	10	3	na	3	0	7	2	73
Design deficiency	5	0	5	8	3	1	5	8	4	3	5	4	na	4	1	0	8	64
Fuel spill	5	3	5	3	2	2	1	5	5	1	2	8	na	1	0	0	1	44
Overload	4	0	0	0	2	1	1	0	0	1	1	0	na	0	0	1	0	11
Suspicious	1	1	0	1	1	1	1	0	0	0	0	2	na	1	0	0	0	9
Control system failure	0	0	2	0	2	0	0	2	0	1	0	0	na	1	0	0	0	8
Collision or overturn	0	0	1	0	1	0	2	0	0	0	0	1	na	0	2	0	0	7
Tobacco products	0	0	0	0	1	0	1	2	0	0	0	0	na	0	0	0	0	4
Construction deficiency	0	0	1	0	0	0	0	0	0	0	1	0	na	0	0	0	0	2
Other ignition factor	8	5	5	4	10	6	7	7	10	9	12	7	na	16	5	8	3	122
Unknown	18	21	25	44	20	31	23	35	37	29	36	52	na	53	45	63	43	575
Total	138	160	178	257	158	166	180	224	214	223	268	290	na	262	193	260	167	3338

Appendix G: Location of fire

Location of fire origin for the Main Dataset 1984-1997

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Midwest subset (84-97)	Main Dataset (84-97)
Engine area	380	334	488	547	377	381	416	539	428	466	574	449	na	398	1954	5777
Operator area	17	17	20	27	20	15	14	29	28	34	27	39	na	27	95	314
Fuel system	8	8	18	11	9	13	4	6	1	7	9	13	na	5	45	112
Hopper	2	4	10	4	4	6	12	14	6	8	9	6	na	8	26	93
Other	52	55	68	87	47	75	89	63	70	67	113	97	na	72	237	955
Unknown	13	10	18	32	23	35	16	27	22	26	38	34	na	30	129	324
Total	472	428	622	708	480	525	551	678	555	608	770	638	na	540	2486	7575*

*** 732 cases reported geographic location for fire origin and were removed**

Location of fire origin for the Midwest Subset 1984-2000

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Midwest subset (84-00)
Engine area	93	123	132	187	105	105	115	170	169	172	203	193	na	187	119	150	102	2325
Operator area	2	3	3	5	6	4	6	6	5	12	13	15	na	15	3	14	7	119
Fuel system	2	1	3	4	6	8	1	3	0	3	2	10	na	2	5	2	4	56
Hopper	0	2	3	1	2	1	6	2	0	3	2	1	na	3	4	5	2	37
Other	14	15	12	30	12	13	13	13	18	17	16	27	na	22	37	47	19	325
Unknown	8	2	4	6	11	17	7	9	6	9	16	12	na	22	8	18	16	171
Total	119	146	157	233	142	148	148	203	198	216	252	258	na	251	176	236	150	3033*

*** 305 cases reported geographic location for fire origin and were removed**

Appendix H: The composition of the material first ignited

Material first ignited for the Main Dataset 1984-1997

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Midwest Subset (84-97)	Main Dataset (84-97)
Crop residue	204	179	238	331	208	253	254	351	254	266	370	319	na	257	1053	3484
Plastic	25	24	31	26	26	19	36	19	21	40	46	49	na	45	206	407
Gasoline	61	42	92	65	58	30	47	50	45	46	38	36	na	15	219	625
Belt or tire	35	38	31	34	29	28	21	43	27	32	44	40	na	23	140	425
Diesel fuel	18	22	20	32	16	17	27	28	29	22	27	29	na	12	117	299
Grease	26	21	47	32	21	24	30	21	21	30	34	20	na	22	109	349
Lube/hyd oil	23	16	28	25	26	18	19	25	30	20	13	21	na	16	100	280
Cotton	0	0	0	0	0	0	0	0	0	0	0	0	na	0	0	0
Other	50	40	99	99	66	69	73	97	94	102	96	87	na	73	334	1045
Unknown	74	79	93	121	75	115	92	132	102	99	171	125	na	115	440	1393
Total	516	461	679	765	525	573	599	766	623	657	839	726	na	578	2718	8307

Material first ignited for the Midwest Subset 1984-2000

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Midwest Subset (84-00)
Crop residue	47	59	50	109	54	59	81	99	80	89	118	112	na	96	93	142	91	1379
Plastic	12	16	10	10	17	11	15	8	10	19	20	34	na	24	15	14	11	246
Gasoline	15	12	33	26	23	7	12	14	19	16	15	21	na	6	5	11	5	240
Belt or tire	14	21	11	8	5	5	5	6	14	18	12	12	na	9	4	5	4	153
Diesel fuel	7	9	7	13	7	7	6	9	8	12	9	15	na	8	2	4	5	128
Grease	4	7	12	9	6	8	5	8	8	12	6	9	na	15	9	4	2	124
Lube/hyd oil	9	3	9	6	7	5	5	9	17	7	7	6	na	10	1	1	2	104
Cotton	0	0	0	0	0	0	0	0	0	0	0	0	na	0	0	0	0	0
Other	8	10	24	39	20	21	25	36	26	26	31	28	na	40	25	28	12	399
Unknown	22	23	22	37	19	43	26	35	32	24	50	53	na	54	39	51	35	565
Total	138	160	178	257	158	166	180	224	214	223	268	290	na	262	193	260	167	3338

Appendix I: Estimated dollar loss for each year reported

	Year	total cases	valid cases	Percent Valid Cases	Total Reported Loss	Average Reported Loss per Case	Total Reported Loss Corrected for Inflation	Average Reported Loss Corrected for Inflation
Main Dataset	84	516	404	78.3%	$3,451,110	$8,542	$5,970,420	$14,778
Main Dataset	85	461	384	83.3%	$3,891,950	$10,135	$6,499,557	$16,926
Main Dataset	86	679	553	81.4%	$5,301,441	$9,587	$8,694,363	$15,722
Main Dataset	87	765	602	78.7%	$5,897,871	$9,797	$9,318,636	$15,479
Main Dataset	88	525	408	77.7%	$4,559,004	$11,174	$6,929,686	$16,985
Main Dataset	89	573	437	76.3%	$4,562,117	$10,440	$6,615,070	$15,137
Main Dataset	90	599	450	75.1%	$4,820,810	$10,713	$6,652,718	$14,784
Main Dataset	91	766	551	71.9%	$6,171,616	$11,201	$8,146,533	$14,785
Main Dataset	92	623	454	72.9%	$4,813,345	$10,602	$6,161,082	$13,571
Main Dataset	93	657	486	74.0%	$5,280,812	$10,866	$6,548,207	$13,474
Main Dataset	94	839	571	68.1%	$6,517,090	$11,413	$7,885,679	$13,810
Main Dataset	95	726	530	73.0%	$6,728,060	$12,694	$7,939,111	$14,979
Main Dataset	96	na	na	na	na	na	na	na
Main Dataset	97	578	411	71.1%	$6,595,526	$16,048	$7,386,989	$17,973
Midwest Subset	98	193	92	47.7%	$1,367,660	$14,866	$1,504,426	$16,352
Midwest Subset	99	260	104	40.0%	$991,545	$9,534	$1,070,869	$10,297
Midwest Subset	00	167	53	31.7%	$842,200	$15,891	$875,888	$16,526