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Canada

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ABSTRACT

The Canadian and U.S.A. fire loss statistics for apartment and office buildings were analyzed to obtain information on fire incidence rates, fire types, death rates and fire department response times. This information was obtained to provide input to, and partly for validation of, the risk-cost assessment model for application to highrise buildings.

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INTRODUCTION

The Canadian and U.S.A. fire loss statistics for apartment and office buildings were analyzed to provide statistical input to, and partly validation of, the risk-cost assessment model which is being developed at the National Fire Laboratory. The risk-cost assessment model is a computer model that can be used to assess the life risks and protection costs in buildings. In this summary report, Canadian fire statistics, obtained previously from Ontario and Alberta, were analyzed to provide the required probability information on fire incidence rates, fire types, death rates and fire department response times. Included in this report is a summary of, and comparison with, relevant U.S.A. fire statistics.

The Ontario fire loss statistics were obtained in collaboration with the Ontario Fire Marshal's Office [1]. They were obtained from two databases: the comprehensive Fire Loss Reporting System (FLRS) that documented all fires in Ontario, from 1983-1990, and the smaller Fire Safety Report (FSR) that contained more detailed information on significant fires, from 1984-1987. The Ontario statistics were analyzed to obtain the required probability information mentioned earlier.

In addition to the Ontario data, suitable U.S.A. fire statistics for the risk-cost assessment model were also obtained in collaboration with the National Fire Protection Association [2]. Fire probabilities based on Ontario and U.S.A. data were compared to determine if there were significant differences. In those cases where there were insufficient Ontario data, the more comprehensive U.S.A. data were used.

The fire statistics for the Province of Alberta, from 1984-1987, were obtained from the Alberta Fire Prevention Branch [3], but the database was found to be too small to be of any significance. The number of fire deaths was basically zero for statistical purposes. The Alberta data could not be analyzed to provide any meaningful probability projections and therefore were not used.

FIRE INCIDENCE

The Ontario fire incidence rates were obtained in the Ontario fire statistics report [1] and are reproduced in Table 1, along with the U.S.A. figures from the National Fire Protection Association report [2]. For office buildings, the Ontario and U.S.A. figures are very close (within 5%), but for apartment buildings, the U.S.A. rate is 2.3 times that of Ontario.

TABLE 1. Fire incidence rates for apartment and office buildings in Ontario and the U.S.A.

ONTARIO				U.S.A.	
Building Type	Year	Rate	Rate Unit	Year	Rate
apartment	1986	2.61E-03	No. of fires / unit	1987	5.90E-03
office	1989	7.68E-06	No. of fires / sq. m	1986	7.30E-06

FIRE TYPES

In the NFL risk-cost assessment model, three design fires are used to represent all possible fire types. The three design fires are:

(1) smouldering fires (non-flaming fires),
(2) non-flashover flaming fires (small fires), and
(3) flashover fires (significant fires).

The probability of occurrence of each of the design fires can be derived only from statistics. Present fire statistics, however, do not provide such direct information and indirect methods, therefore, must be used.

Initially, it was intended to use the extent of fire spread to separate the fires into the three design fire types and to derive the probability of occurrence of each fire type, based on the number of fires in each type. This method was used in an earlier study [4] and in the U.S.A. study [2]. In Ontario, however, the extent of fire spread was recorded only in the FSR database, which was established for significant fires and is not an accurate database for all fires [1]. Because of this bias, an alternative method was used, based on significant changes in the death rate (the number of deaths per 1000 fires) which are available in both the FLRS and FSR databases [1]. This method was also used in the earlier study [4].

The death rates (number of deaths per 1000 fires) versus fire loss ($) for both sprinklered and non-sprinklered apartment buildings are plotted in Figures 1 to 8:

- Figures 1-2 are based on FLRS data, 1983-1990;
- Figures 3-4 are based on FLRS data, 1984-1987;
- Figures 5-6 are based on FSR data, 1984-1987; and
- Figures 7-8 are based on U.S.A. data, 1985-1989.

No equivalent plots were made for office buildings because there was only one death in office buildings in both Ontario and in the U.S.A. during those years.

Figures 1 to 6 show that there are no obvious changes in death rate that can be used to separate the fires into the three fire types. This could be the result of the fact that the databases are not large enough. That this is the case is evident by an examination of the plots. The plots covering seven years of data show smoother patterns than those covering four; with those pertaining to non-sprinklered buildings smoother than those pertaining to sprinklered buildings (fewer deaths). The bias of the FSR data is clear, with much higher death rates at lower fire losses than those of the FLRS database. Figures 7 and 8 also show that there are no sharp changes in the death rate in the U.S.A. plots, although there is a general increase in the death rate with property loss. This again could be the result of the fact that the database is not large enough. In an earlier study using a larger database for all residential buildings [4], not just for apartment buildings, sharp jumps in the death rate were seen.

With the use of changes in death rate to separate the fires not possible, a different methodology, based on the U.S.A. fire property loss characteristics, was used. In the U.S.A. analysis [2], the number of fires in each of the three fire types was obtained based on the extent of fire spread. Using the obtained number of fires in each of the three fire types and a separate table showing the distribution of the number of fires in each property loss range, the property loss value that marks the division between non-flashover and flashover fires can be obtained as follows:

From Table 14 (E) in Ref. 2, the combined percentage of smouldering and non-flashover flaming fires is 81.7% for non-sprinklered apartment buildings. The number of fires in this combined category, not counting those of unknown and zero property loss, can be obtained from Table 2 in Ref. 2 as: (69,157 - 18,370) × 0.817 = 41,493. Also from Table 2 in Ref. 2, the 41,493rd fire occurs in the property loss range of US \$8,000 - \$8,999. The transition from non-flashover fires to flashover fires can therefore be considered to occur at US \$8,000 for non-sprinklered apartment buildings. Using the same analysis, the transition for sprinklered apartment buildings can also be determined to be at US \$15,000.

Assuming that the relationship between fire type and property loss in the Ontario and U.S.A. fire statistics is similar and that the U.S.A. transition dollar figures can be simply changed to Canadian dollar figures when applied in Ontario, the transition to flashover fires for non-sprinklered apartment buildings in Ontario can be considered as CDN \$8,000 and for sprinklered apartment buildings, CDN \$15,000. For non-sprinklered apartment buildings, the \$8,000 transition figure can be easily applied to the Ontario data to obtain the percentage of flashover fires. From Table 2 in Ref. 1, of the 14,162 fires in Ontario for non-sprinklered apartment buildings, 2,594 or 18.3% are above \$8,000 and can be considered flashover fires. For sprinklered buildings, however, the \$15,000 figure cannot be easily applied because the Ontario study shows all fires above \$10,000 as one group. To resolve this problem, the U.S.A. ratio of the number of flashover fires and those having a property loss of \$10,000 or more is applied to the Ontario data. From Table 1 in Ref. 2, of the 155 U.S.A. fires having a property loss of \$10,000 or more, 119 are flashover fires, a ratio of 0.768. The number of flashover fires in Ontario for sprinklered apartment buildings can be obtained from Table 3 in Ref. 1 as: 395 (which is the total number of fires above \$10,000) × 0.768 = 303. With 303 out of a total of 5,996 fires (also from the Table 3 in Ref. 1), the percentage of flashover fires in Ontario for sprinklered apartment buildings is 5.1%.

To separate the smouldering fires from the combined smouldering and non-flashover flaming fires, the fires in the lowest property loss range (\$0 - 999) are considered since smouldering fires are small fires (by definition) and therefore do not usually cause high property losses. In the U.S.A. study (Ref. 2, Table 13), the percentages of small fires that ended in smouldering fires were found to be 33.2% for non-sprinklered apartment buildings and 24.5% for sprinklered buildings. Assuming that the fire characteristics are similar between Ontario and the U.S.A., these percentage values can be applied to the Ontario data [1] to obtain the percentages of smouldering fires. The number of smouldering fires for non-sprinklered apartment buildings in Ontario can be obtained from Table 2 in Ref. 1 as: 8,166 (which is the number of fires less than \$999) × 0.332 = 2,711.

With 2,711 out of a total of 14,162 fires (also from Table 2 in Ref. 1), the percentage of smouldering fires in Ontario for non-sprinklered apartment buildings is 19.1%. For sprinklered apartment buildings in Ontario, the percentage of smouldering fires can be similarly obtained as 18.2%.

Once the number of flashover fires and smouldering fires are determined, the remaining fires are considered non-flashover flaming fires. The percentages of smouldering fires, non-flashover flaming fires and flashover fires for non-sprinklered and sprinklered apartment buildings are summarized in Tables 2 and 3. The Tables show that the effect of sprinklers is to redistribute most of the flashover fires into non-flashover flaming fires. This is reasonable since the effect of sprinklers, when the sprinklers are activated, is to prevent small fires from becoming major fires. Also shown in these two Tables are the U.S.A. figures. The Tables show that the Ontario and U.S figures are similar, which is expected since lifestyles in the two countries are lifestyles.

TABLE 2. Apartment fire types in Ontario and the U.S.A., no sprinklers (FLRS, 1983-1990 & U.S.A. data, 1985-1989)

ONTARIO			U.S.A.
Fire Type	No. of Fires	Percent of Total	Percent of Total
Smouldering	2,711	19.1	18.7
Non-Flashover	8,857	62.6	63.0
Flashover	2,594	18.3	18.3
Total	14,162	100.0	100.0

TABLE 3. Apartment fire types in Ontario and the U.S.A., with sprinklers (FLRS, 1983-1990 & U.S.A. data, 1985-1989)

ONTARIO			U.S.A.
Fire Type	No. of Fires	Percent of Total	Percent of Total
Smouldering	1,096	18.2	21.4
Non-Flashover	4,599	76.7	72.3
Flashover	303	5.1	6.3
Total	5,996	100.0	100.0

Using the same methodology, the percentages of smouldering, non-flashover flaming and flashover fires, based on the FLRS, 1984-1987 and the FSR, 1984-1987 databases [1], can also be obtained. For comparison purposes, these values are summarized in Tables 4 to 7. Tables 4 and 5 show that the percentages based on the four-year span of the FLRS data are basically the same as those based on the seven-year span (Tables 2 and 3). Tables 6 and 7 show, as expected, the skewed nature of the FSR database towards significant fires. However, the effect of sprinklers to redistribute most flashover fires into mostly non-flashover flaming fires is still apparent.

TABLE 4. Apartment fire types in Ontario, no sprinklers (FLRS, 1984-1987)

Fire Type	No. of Fires	Percent of Total
Smouldering	1,360	19.6
Non-Flashover	4,392	63.4
Flashover	1,175	17.0
Total	6,927	100.0

TABLE 5. Apartment fire types in Ontario, with sprinklers (FLRS, 1984-1987)

Fire Type	No. of Fires	Percent of Total
Smouldering	537	18.3
Non-Flashover	2,269	77.2
Flashover	132	4.5
Total	2,938	100.0

TABLE 6. Apartment fire types in Ontario, no sprinklers (FSR, 1984-1987)

Fire Type	No. of Fires	Percent of Total
Smouldering	30	8.3
Non-Flashover	138	38.0
Flashover	195	53.7
Total	363	100.0

TABLE 7. Apartment fire types in Ontario, with sprinklers (FSR, 1984-1987)

Fire Type	No. of Fires	Percent of Total
Smouldering	8	15.7
Non-Flashover	38	74.5
Flashover	5	9.8
Total	51	100.0

The U.S.A. fire-type percentages for office buildings [2] are reproduced in Table 8, since insufficient Canadian data exist. Compared with apartment buildings, there are slight increases in smouldering and flashover fires with a corresponding decrease in non-flashover flaming fires. The effect of sprinklers is the same as in apartment buildings, redistributing most of the flashover fires into mainly non-flashover flaming fires.

TABLE 8. Office fire types in the U.S.A., no sprinklers and with sprinklers (U.S.A. data, 1985-1989)

Fire Type	Percent of Total Fires	
	No Sprinklers	With Sprinklers
Smouldering	22.3	29.5
Non-Flashover	53.5	65.4
Flashover	24.2	5.1
Total	100.0	100.0

FIRE DEATHS

The death rates in Ontario [1] and the U.S.A. [2] for apartment buildings are summarized in Table 9 under four different combinations of smoke alarm and sprinkler protection. The relative risk factors to the reference option of no smoke alarm and no sprinkler protection are shown in Table 10. No similar tables are shown for office buildings because there was only one death recorded in both Ontario and the U.S.A. and therefore was not sufficient to construct such tables.

The Tables show that there is a decrease in risk with sprinkler protection. However, both Ontario and U.S.A. data show an anomaly: that the risk was unchanged or higher if smoke alarms were installed. For example, the data show that without sprinkler protection, the installation of smoke alarms would not affect the risk. With sprinkler protection, the installation of smoke alarms would increase the risk. These results cannot be explained and could be the result of improper recording of smoke alarm and sprinkler information. In addition, the presence of a smoke alarm or sprinklers does not guarantee that they were installed throughout the building and that they were working at the time of fire.

Table 10 also shows the deficiencies of small databases: the FLRS four-year subset having less visible trends, and the biased FSR data having exaggerated trends.

Table 9 shows that the U.S.A. death rates are roughly half those of Ontario. It should be interesting to note that this is the opposite of the fire incidence rate where, as shown in Table 1, the U.S.A. figure is about twice that of Ontario. Since the death rate per apartment unit is the product of the incidence rate (number of fires per unit) times the death rate (number of deaths per fire), the death rate per apartment unit is about the same in Ontario and in the U.S.A. This is consistent with the general statistical findings that the fire death rate per capita is about the same in Canada and the U.S.A.

Ignoring, for the moment, that there are still questions on their accuracy, Table 10 shows that the relative risk factors are about the same in Ontario and in the U.S.A. The relative risk factors are more important in comparative risk assessments since they show the relative effectiveness of smoke alarm and sprinkler protection measures.

TABLE 9. Death rates in Ontario and U.S.A. apartment buildings for different combinations of smoke alarm and sprinkler protections

Apartment Buildings	Death Rates (No. of deaths / 1000 fires)			
	NS & NA	NS & A	S & NA	S & A
Ontario: 83-89 (FLRS)	15.8	16.2	4.67	5.6
84-87 (FLRS)	16.7	16.0	4.66	10.5
84-87 (FSR)	159.0	290.0	83.30	25.6
U.S.A.: 85-89	9.2	8.7	1.20	3.2

Note: A Smoke alarm installed
NA No smoke alarm installed
S Sprinklers installed
NS No sprinklers installed

TABLE 10. Relative risk factors in Ontario and U.S.A. apartment buildings for different combinations of smoke alarm and sprinkler protections

Apartment Buildings	Relative Risk Factors			
	NS&NA / NS&NA	NS&A / NS&NA	S&NA / NS&NA	S&A / NS&NA
Ontario: 83-89 (FLRS)	1.00	1.03	0.30	0.35
84-87 (FLRS)	1.00	0.96	0.28	0.63
84-87 (FSR)	1.00	1.82	0.52	0.16
U.S.A.: 85-89	1.00	0.95	0.13	0.35

Note: A Smoke alarm installed
NA No smoke alarm installed
S Sprinklers installed
NS No sprinklers installed

FIRE SERVICES

The time elapsed between the start of a fire and the instant that manual fire suppression by the fire services begins is composed of five separate steps [1]:

1. Alarm initiation or notification time: starts with fire ignition and ends when the fire department gets the notification of the fire.
2. Dispatch time: the time it takes for the first crew to be alerted of the fire after the alarm is received by the dispatcher.
3. Preparation time: the time it takes for the firefighters to get ready.
4. Travel time: the time it takes for the fire crew to travel to the scene of the fire.
5. Set-up time: begins when the firefighters arrive at the scene and ends when they begin fire suppression operations.

All five steps are affected by many factors, such as the distance of the building from the fire department, the type of fire department, the time of day, the weather, and the traffic conditions to name a few (for details see Ref. 1, p. 29-30).

A survey of fire department response times was carried out with fire departments in Ontario [1] and the results are summarized in Table 11. Only the ranges of response times for the various steps are shown because of the inherent variability mentioned above. The survey was based mostly on composite and full-time fire departments, since volunteer fire departments are normally found in rural areas where there are usually no high-rise buildings. For reference, the numbers and types of fire departments in Ontario are shown in Table 12.

In addition to the survey, a test of set-up times required was performed by a regular crew of the Mississauga Fire Department at its training centre [1] and the results summarized in Table 13. The three scenarios were devised to cover typical operations of a fire department fighting a high-rise fire (for exact conditions, see Ref. 1). The results of the tests show that the range of the set-up times is between 3 and 7 minutes, which is consistent with the results of the survey.

TABLE 11. Survey of fire department response times

	Time			Comments
Dispatch	60 - 90 sec			- representative of full-time
Preparation	30 - 60 sec			fire departments
Travel	2 - 5 min			- volunteers notified at home would take longer
Set-Up	Average	Range	(delta t) / Floor	- fire on fourth floor
apartment	4 min	3 - 7 min	1 min	- decreased if firefighters'
office	4 min	3 - 7 min	1 min	elevator available
Effect of type of construction	no effect			- however, hose cabinets are easier to locate so faster in open concept offices

TABLE 12. Fire department types in Ontario

Type	Number	Percent (%)
Full-Time	34	5
Composite	100	15
Volunteer	522	80
Total	656	100

TABLE 13. Summary of fire department test set-up times

Scenario	Conditions	Hydrant Hook-up Time (min:sec)	Fire Suppression Activities Time (min:sec)	Total Set-up Time (min:sec)
1	- windows shut - use of standpipe only - clear visibility	none	3:56	3:56
2	- first hydrant inoperable - standpipe dry - smoke-filled floor	4:05	2:28	6:33
3	- aerial apparatus used	none	3:16	3:16

CONCLUSIONS

The Ontario, Alberta and U.S.A. fire loss statistics for apartment and office buildings were analyzed to obtain information on fire incidence rates, fire types, death rates and fire department response times. This information was obtained to provide input to, and partly for validation of, the risk-cost assessment model for application to highrise buildings.

Ontario has the most comprehensive, computer-based, fire statistics in Canada, whereas the Alberta data were found to be too limited to be of any significance. Until other data are available, the Ontario data will be assumed to be representative of Canada for use in the risk-cost assessment model.

The fire incidence rates obtained were found to be comparable between Ontario and U.S.A. figures for office buildings. For apartment buildings, however, the U.S.A. figure is about twice that of the Ontario figure.

The probabilities of the three fire types (smouldering, non-flashover flaming and flashover fires) could not be obtained directly from the Ontario data. For apartment buildings, the probabilities were obtained by applying the U.S.A. transition characteristics from smouldering to non-flashover flaming and from non-flashover flaming to flashover fires to the Ontario data. The results show that the probabilities of the three fire types are comparable between Ontario and the U.S.A. figures. The results also show that the effect of sprinklers is to redistribute most of the flashover fires into non-flashover flaming fires, which is reasonable since the effect of sprinklers is to prevent flaming fires from becoming major fires. For office buildings, similar probabilities of fire types could not be obtained for Ontario because insufficient data were available to make a projection. For application to Canadian office buildings, the U.S.A. findings could be used.

The effect of different combinations of smoke alarm and sprinkler protection on the death rate was also determined for both Ontario and the U.S.A. Only results for apartment buildings were obtained because there was insufficient data for office buildings. The results show that the sprinkler protection reduces the death rate by a factor of three.

However, the results also show that the installation of smoke alarms does not reduce the death rate. This is an anomaly which could be the result of improper recording of the smoke alarm information in the database. In addition, the presence of a smoke alarm or sprinklers does not guarantee that they were installed throughout the building and that they were working at the time of fire. This suggests that a careful review of how fire information is gathered is needed.

The results also show that the death rate per fire in the U.S.A. is about half of that in Ontario. This is the opposite of the fire incidence rate (number of fires per apartment unit) where the rate in the U.S.A. is about twice that in Ontario. The net result is that the death rate per apartment unit is about the same in Ontario and the U.S.A., which is consistent with the general statistical findings that the death rate per capita is similar in Canada and the U.S.A.

Finally, information on fire department response times was summarized. This information was obtained in Ref. 1 based on a survey of fire departments in Ontario and tests conducted by the Mississauga Fire Department.

REFERENCES

1. Mailvaganam, S., Yung, D., Prencipe, M., "Ontario Fire Loss Statistics for the Risk-Cost Assessment Model", IRC Internal Report No. 622, NRC, February 1992.
2. Hall, J., "Special Analysis: U.S.A. Statistical Data for the Risk-Cost Assessment Model", National Fire Protection Association contract report to D. Yung, National Fire Laboratory, NRC, January 1992.
3. Wijayasinghe, M., "Alberta Fire Statistics, 1984-1987", Alberta Fire Prevention Branch special report to D. Yung, National Fire Laboratory, NRC, April 1991.
4. Takeda. H. and Yung, D., "Fire Types and Probabilities in Residential Buildings", IRC Fire Research News, Issue No. 61, NRC, Winter 1991.

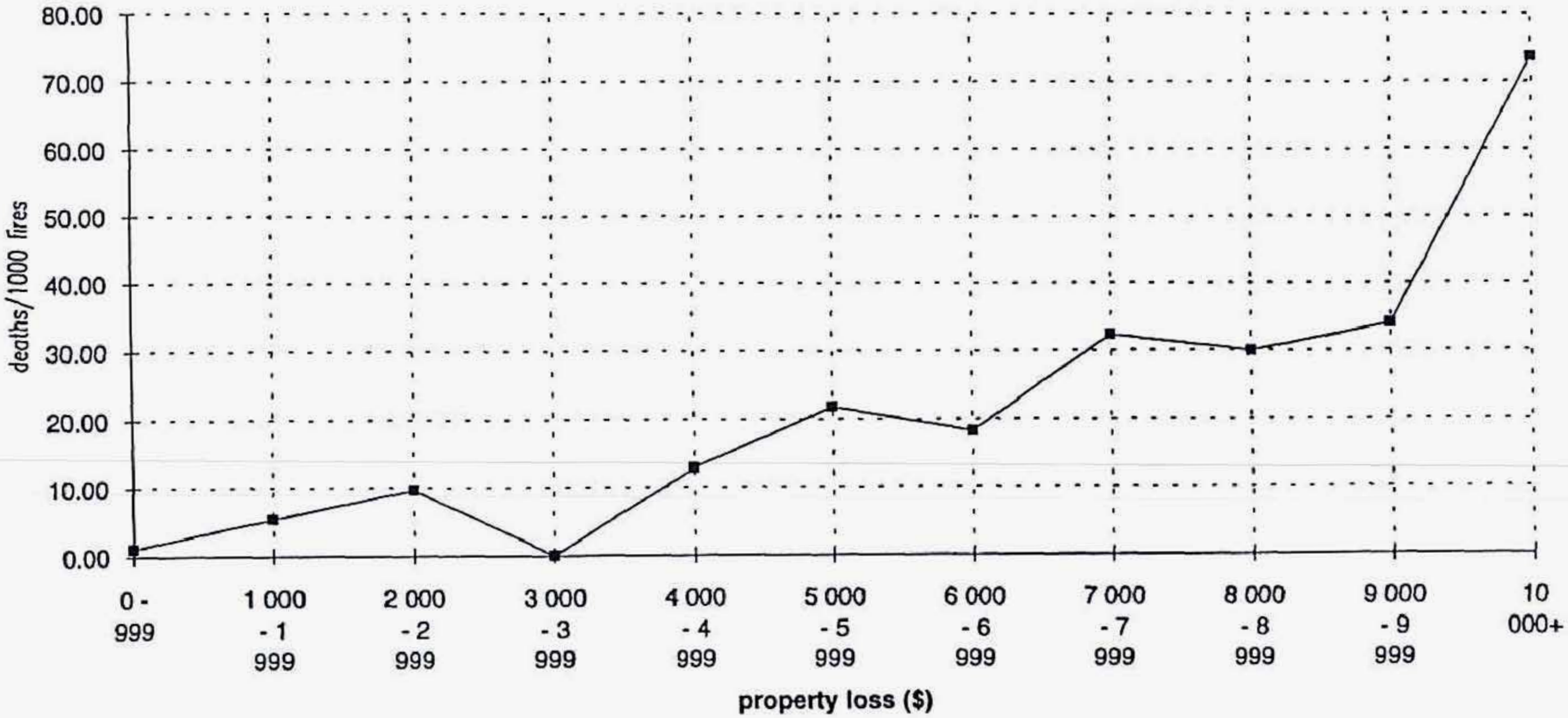

FIGURE 1. Deaths/1000 fires vs property loss for apartments in Ontario, no sprinklers (FLRS, 1983-1990)

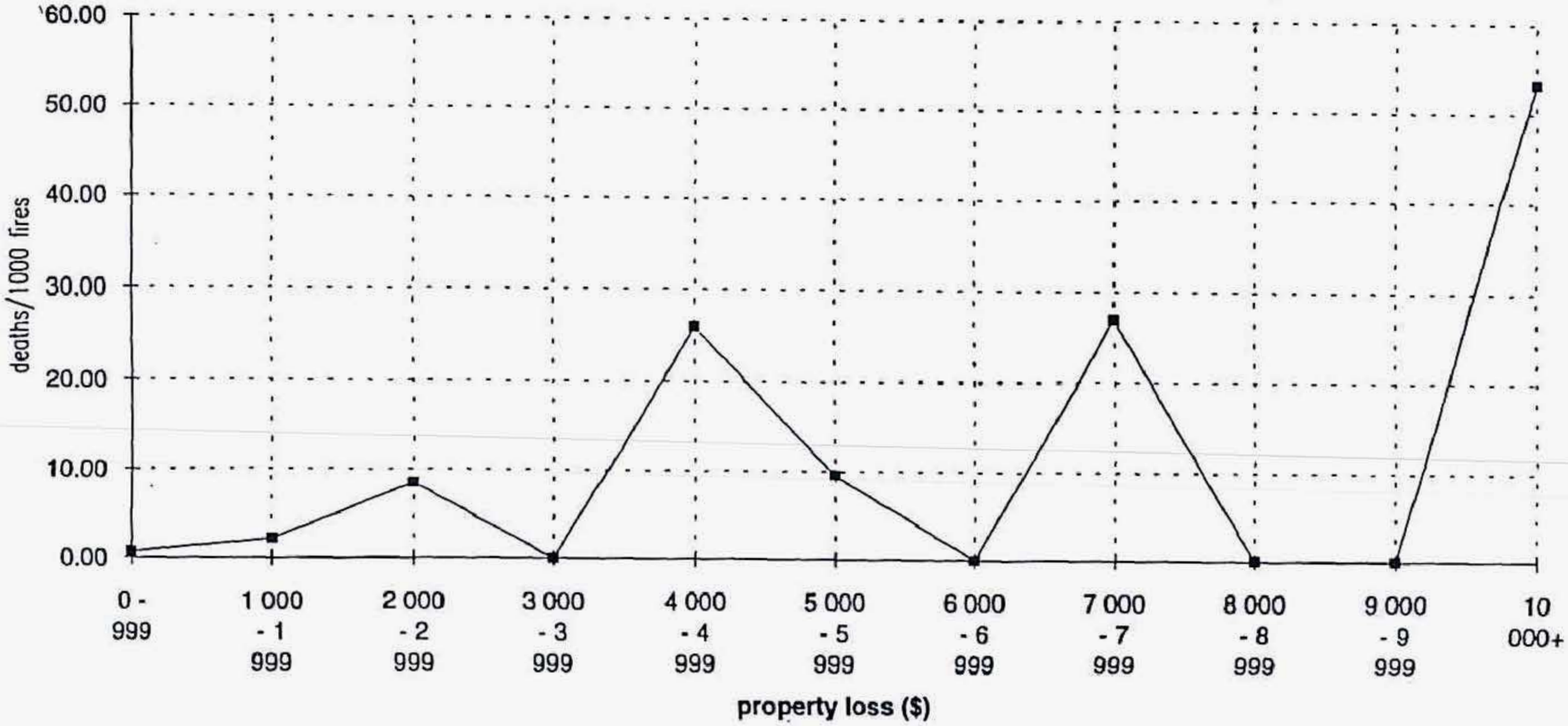

FIGURE 2. Deaths/1000 fires vs property loss for apartments in Ontario, with sprinklers (FLRS, 1983-1990)

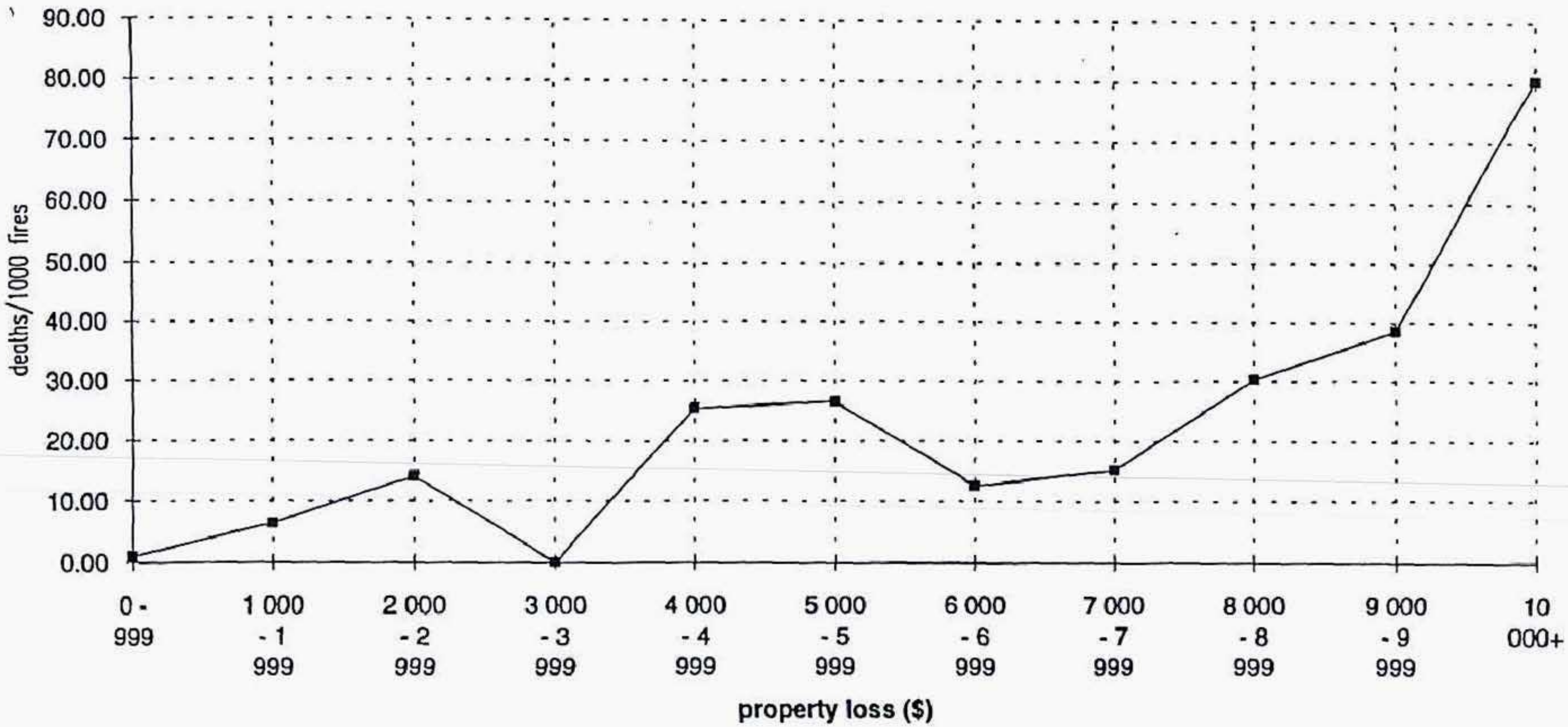

FIGURE 3. Deaths/1000 fires vs property loss for apartments in Ontario, no sprinklers (FLRS, 1984-1987)

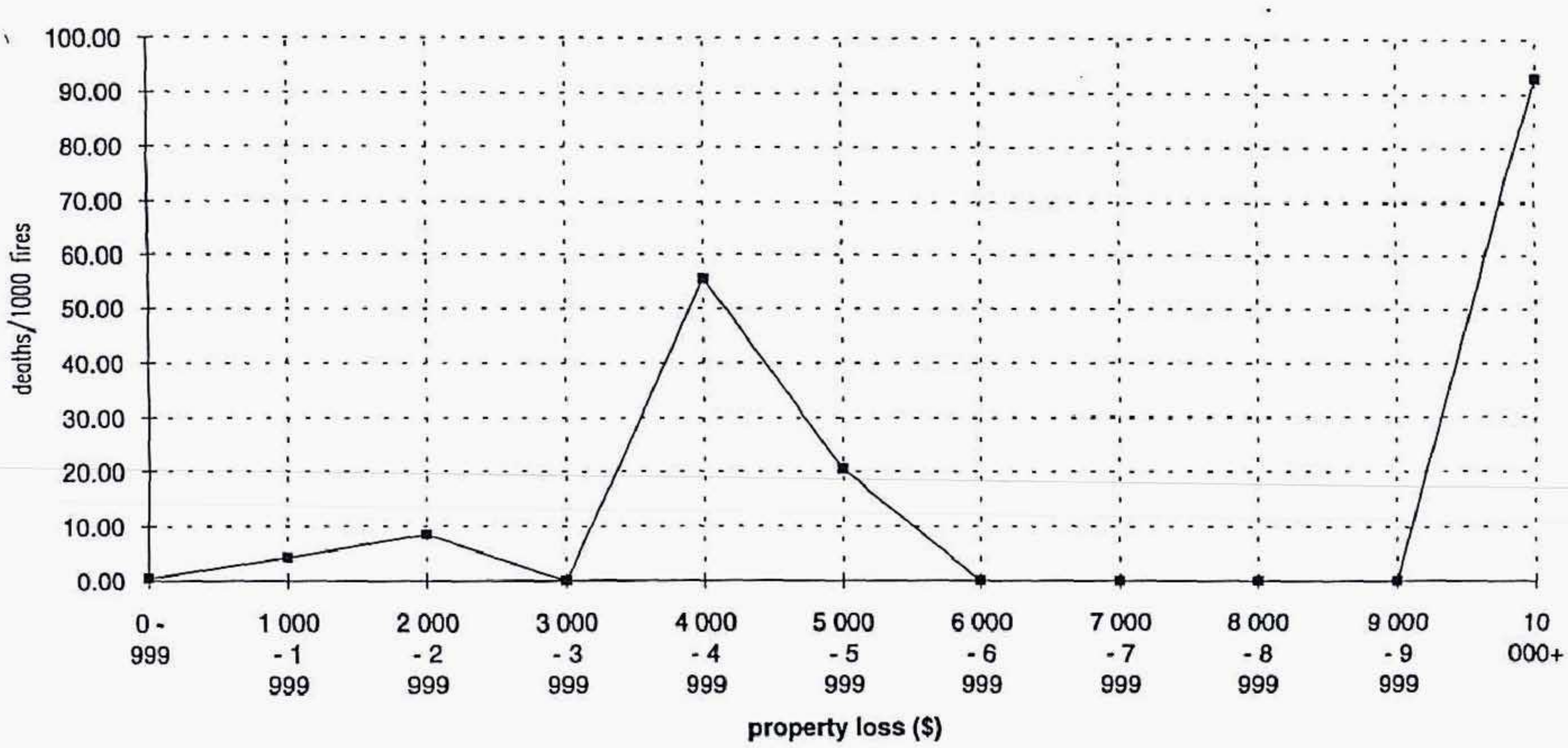

FIGURE 4. Deaths/1000 fires vs property loss for apartments in Ontario, with sprinklers (FLRS, 1984-1987)

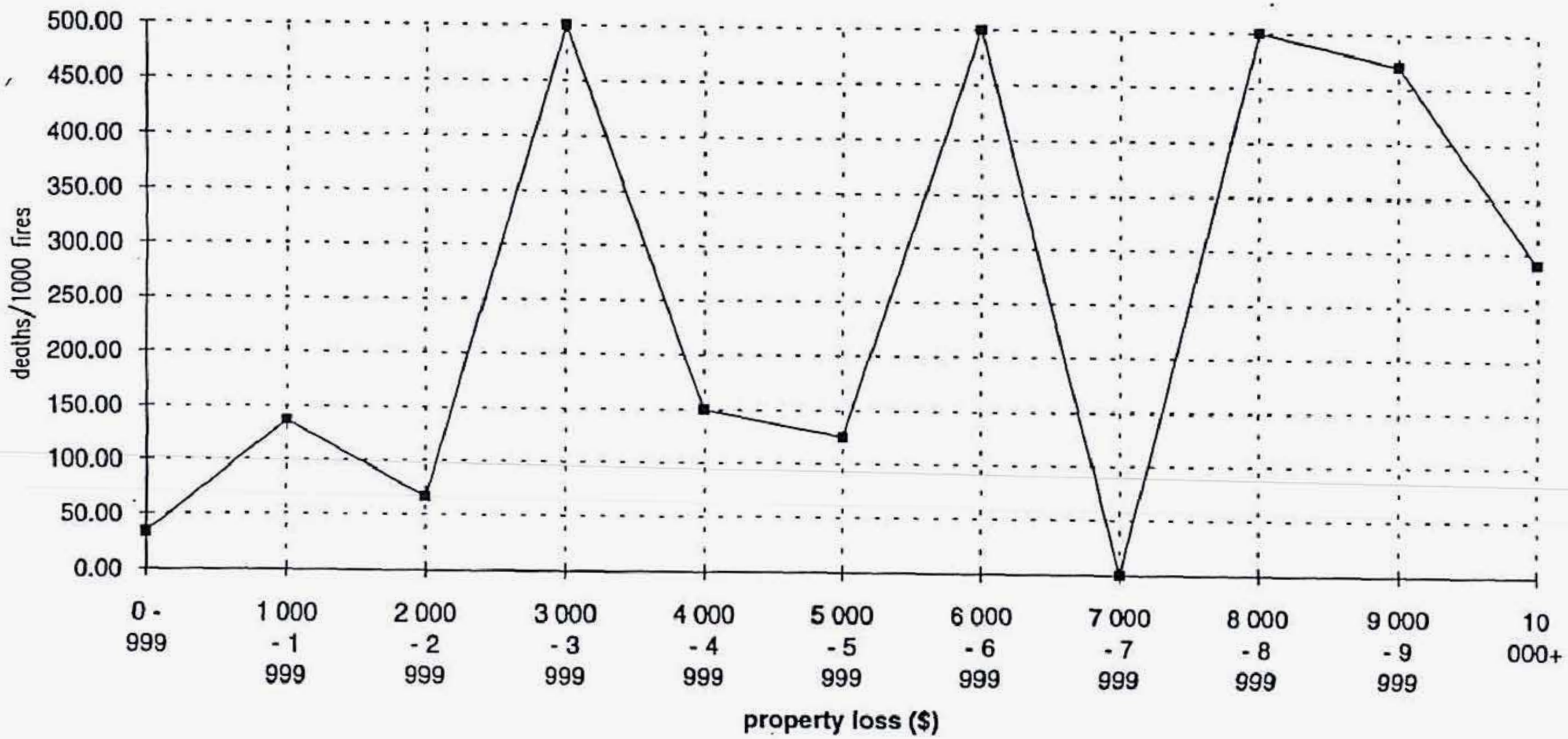

FIGURE 5. Deaths/1000 fires vs property loss for apartments in Ontario, no sprinklers (FSR, 1984-1987)

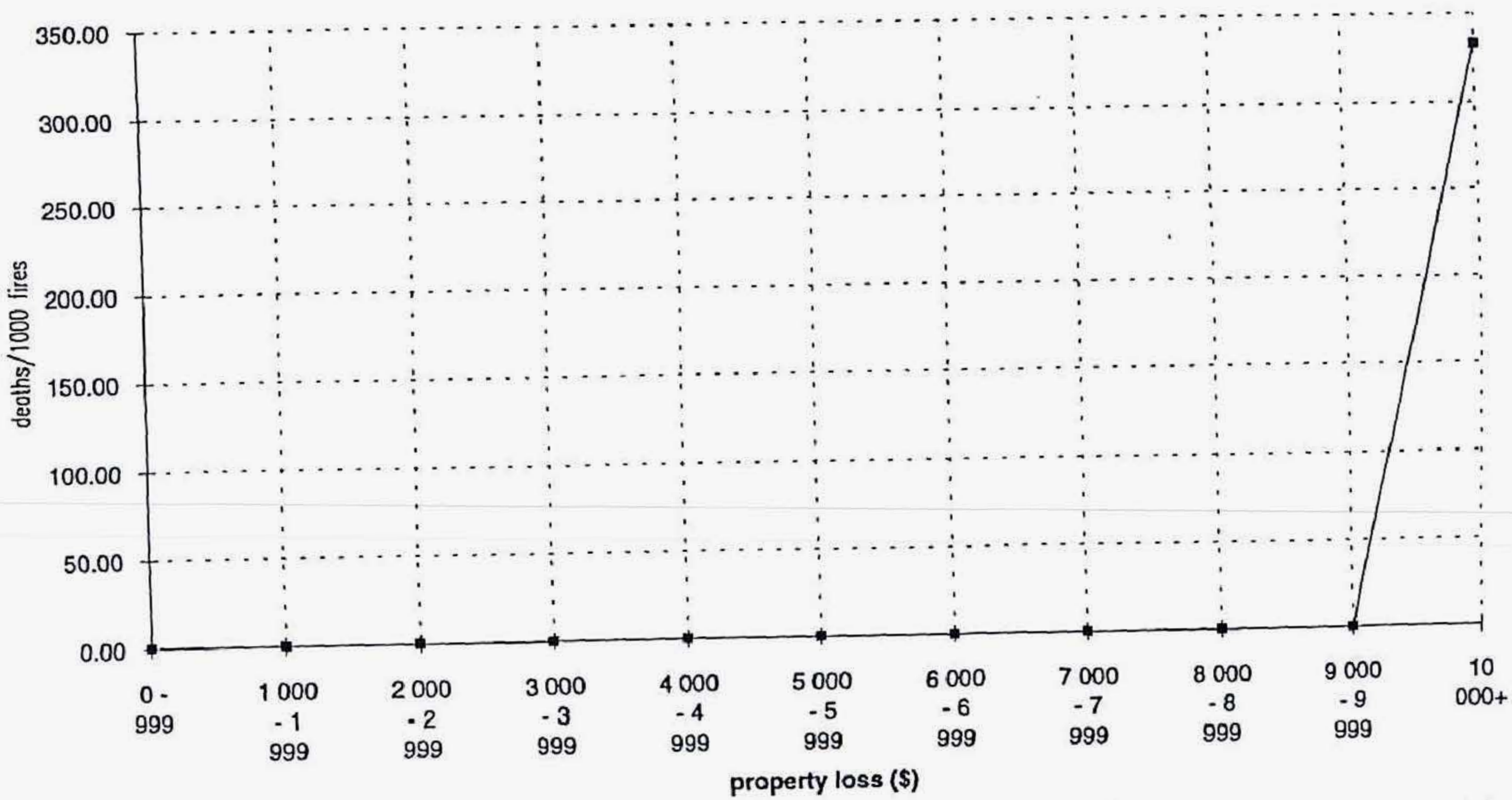

FIGURE 6. Deaths/1000 fires vs property loss for apartments in Ontario, with sprinklers (FSR, 1984-1987)

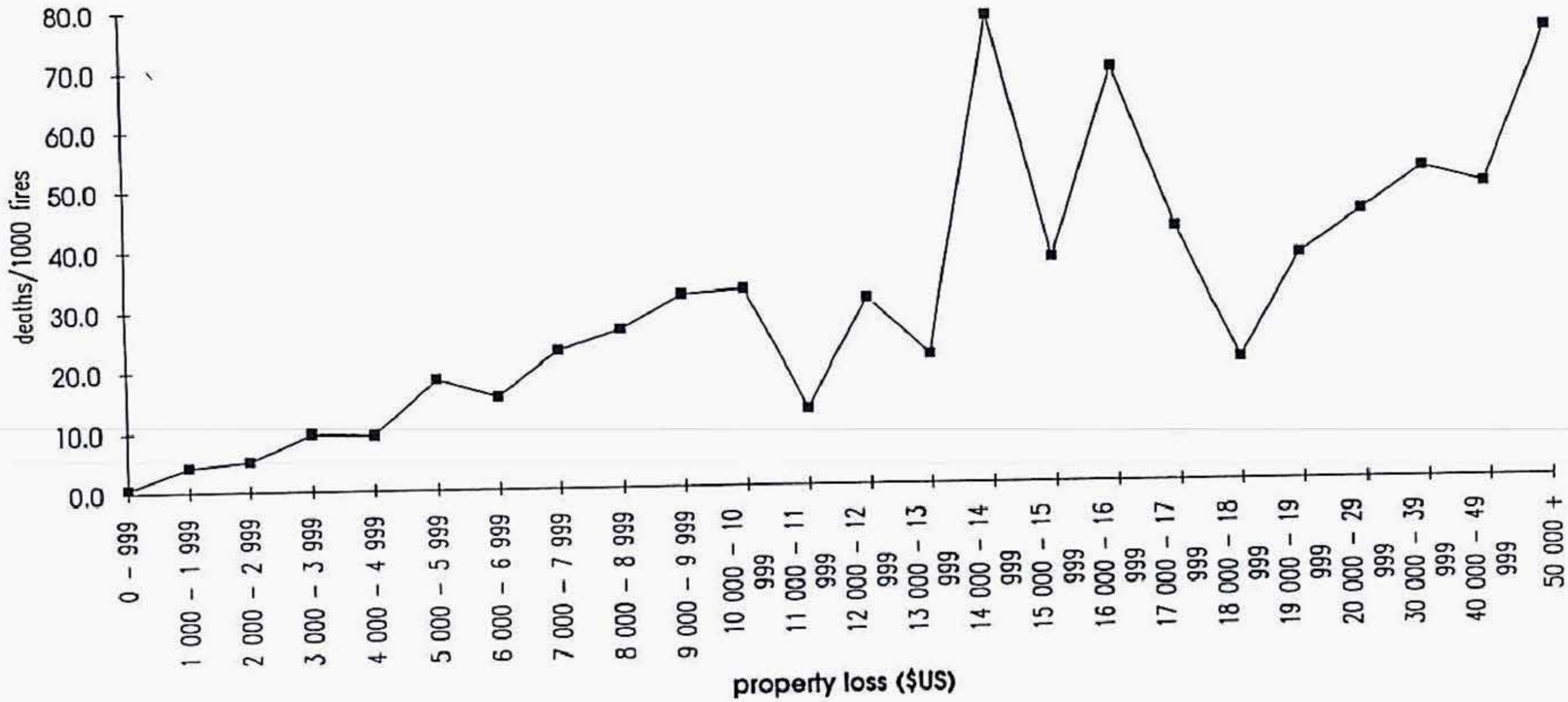

FIGURE 7. Deaths/1000 fires vs property loss for apartments in the U.S., no sprinklers (1985-1989)

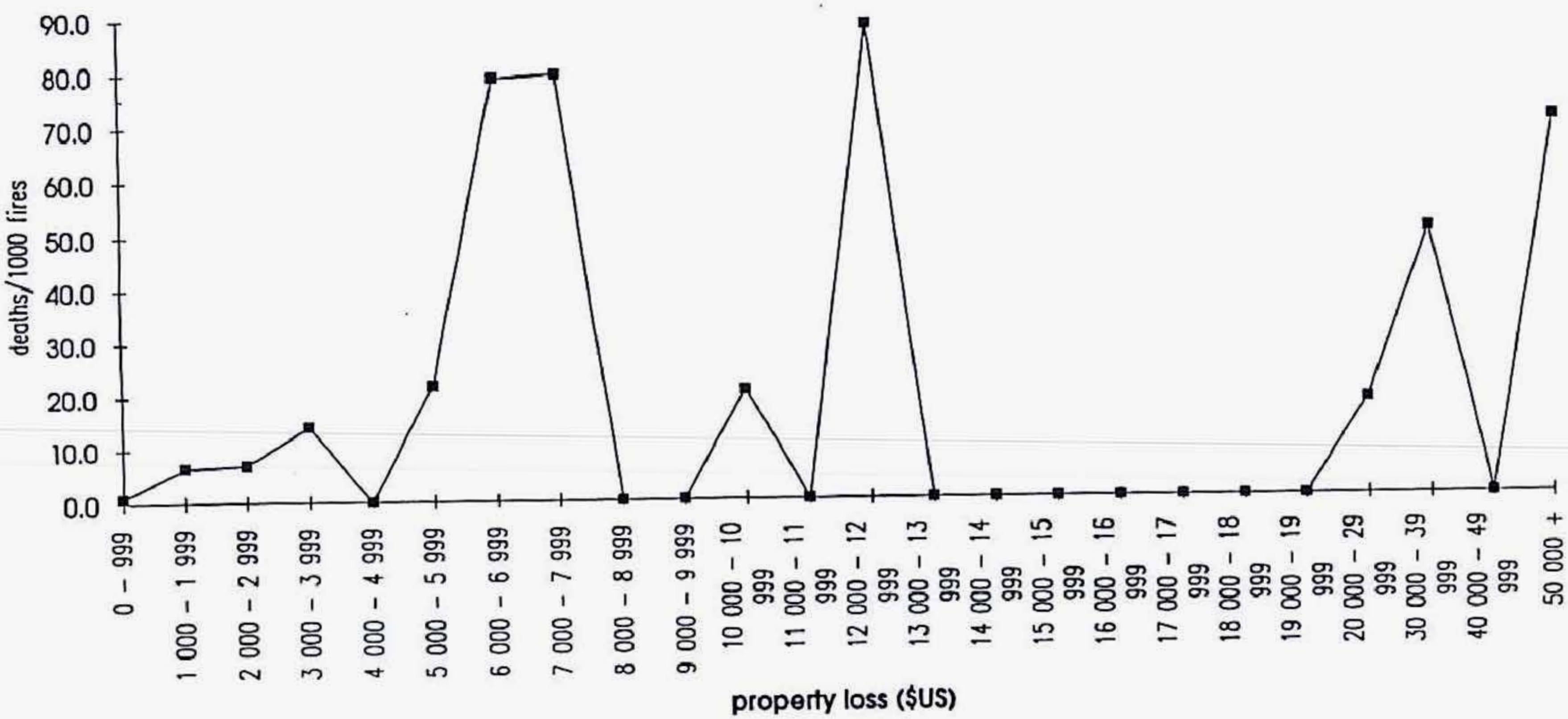

FIGURE 8. Deaths/1000 fires vs property loss for apartments in the U.S., with sprinklers (1985-1989).