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A Statistical Analysis of Bell System Building Fires, 1971–1977

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About 200 fires in Bell System buildings and adjacent grounds (excluding Western Electric) are reported to AT&T each year; the actual number of fires that occur may be somewhat higher. The dollar damage of reported fires (excluding only the $60 million fire in New York City on February 27, 1975) is reasonably modeled above the median by a log normal probability density function. This paper introduces a detailed taxonomy of fires, showing substantial differences in their frequency and costliness. The paper concludes with various special topics: (i) an analysis of employee injuries and service interruptions caused by fire; (ii) the correlation of business hours with fire frequency and building occupancy with fire severity; (iii) the methods used to fight fires; (iv) an analysis of multiple fires in buildings and of a cluster of fires in the Greater New York area in March 1975.

I. INTRODUCTION

Fires occurring in Bell System operating company or Long Lines telephone buildings or adjacent grounds, but not fires in Western Electric plants, are reported to AT&T on a standard form entitled "American Telephone and Telegraph Company Fire Report—Buildings" (Form E-5000), issued in 1962 and revised in 1969 and 1976. This paper analyzes approximately 1500 of these reports, covering fires that occurred in the years 1971 through 1977. Although Bell System summary statistics on fires go back a decade or more, few reports on fires prior to 1971 are, apparently, now available. The issuance of a fire report is governed by the following definition of a fire:

> Any occurrence that produces heat or flame and smoke in telephone company property or leased space, that affects service, causes property or equipment damage, and/or endangers inhabitants.

For the purpose of this paper, this has been interpreted to mean that a fire is characterized by an open flame, arcing, or sparks, visible smoke, or a combination of these; if the fire is out before it is detected, the site is marked by ashes, charred areas, or discoloration. Furthermore, an explosion is counted as a fire. However, a burning odor unaccompanied by smoke that cannot be traced to evidence of the above nature is not counted as a fire. All fires on company-occupied premises, either owned or leased, are supposed to be reported. Specifically, in this paper a fire is included if (*i*) it begins on non-Bell property and spreads to Bell property, damaging it (including water damage by fire fighters) or (*ii*) it occurs in a vehicle parked on Bell premises. However, a fire is not included if (*i*) it occurs in a PBX, telephone closet, or similar place in a building owned or leased by the telephone user, (*ii*) it occurs in a Bell-owned car or truck off Bell premises, (*iii*) it occurs on adjacent property but does not spread to Bell property, (*iv*) it occurs in Bell System outside plant such as manholes and cables, or (*v*) it occurs in a Bell-owned building not being used for telephone purposes and slated for eventual demolition and replacement (often, these are vacant but sometimes they are rented to tenants for a few months). Car and truck fires off Bell premises are recorded on a standard form entitled "American Telephone and Telegraph Company Fire Report—Motor Equipment" (Form E-5000 ME).

It is quite clear that reported fires do not represent all the building fires in the Bell System under the above definitions. Very small fires, such as a lighted match dropped on a carpet and immediately stamped out, are rather unlikely to be reported. Also, since fires are relatively rare events, employees may not be aware of the reporting procedure to be followed.

The "Report of Abnormal Service Conditions" (Form E-3877), telephoned to AT&T by operating companies when telephone service is threatened or interrupted, includes a few building fires (10 to 15 per year). Table I shows that over two-thirds of these fires are also included in the fire reports. If service reports and fire reports are filed independently, this yields an approximate estimate of under-reporting of fires.

Table I — Reports of abnormal service conditions involving building fires

	1972	1973	1974	1975	1976	1977	Total
Fire report	8	13	5	11	11	7	55
No fire report	3	3	3	4	7	1	21

This paper is restricted to fires reported to AT&T, and the reader should keep this potential under-reporting of Bell System fires in mind. Specifically, always ask the question: Are reported fires typical of *all* fires with respect to the characteristic under discussion?

There are several reasons why damage information in the fire report should be regarded with caution. These estimates are highly rounded (to quantities such as $100, $200, $500); furthermore, they are usually made a day or so after the fire, long before the actual bills are in. The dollar values presumably reflect replacement costs, and do not allow for depreciation; furthermore, there is no indication whether labor costs associated with clean-up and repair have been included. If the fire does less than $32 or so in damage, there is a strong possibility that it will be rounded down to zero; over 30 percent of all fires are so reported. There is no reporting mechanism for providing AT&T with more accurate follow-up reports of fire costs. However, trends in costs and comparisons of different cost distributions should be relatively immune to these problems.

II. BELL SYSTEM BUILDING FIRE EXPERIENCE

This section, the core of the paper, summarizes Bell System building fire experience. The first two parts analyze year-by-year changes in the number of fires per year and the probability density function of fire damage for the Bell System as a whole. The third part presents a detailed taxonomy of fires, showing which kinds are most frequent or most costly.

2.1 Number of fires per year

Table II and Fig. 1 summarize the number of Bell System building fires (excluding 73 Bell Canada fires, since Bell Canada left the System in 1975) which occurred from 1971 through 1977. The upper set of points in Fig. 1 includes all fires, no matter how small the damage, but the lower set includes only those fires with reported damages of $32 or more. A statistical chi-squared test on the Poisson counts[1] rejects (at the 0.02 level) the null hypothesis that the average number of fires per year is constant; in fact, the figure suggests that there has been a downward drift. However, this inhomogeneity can be explained by differential diligence from year to year in reporting very small fires, for the same test on the homogeneity of Poisson counts confirms that more expensive fires occur at a constant average rate of a little more than 100 per year.

Table II — Bell System fire frequency, 1971–1977

	1971	1972	1973	1974	1975	1976	1977
All fires	244	209	186	191	194	174	212
Fires over $32	120	102	97	100	95	108	104

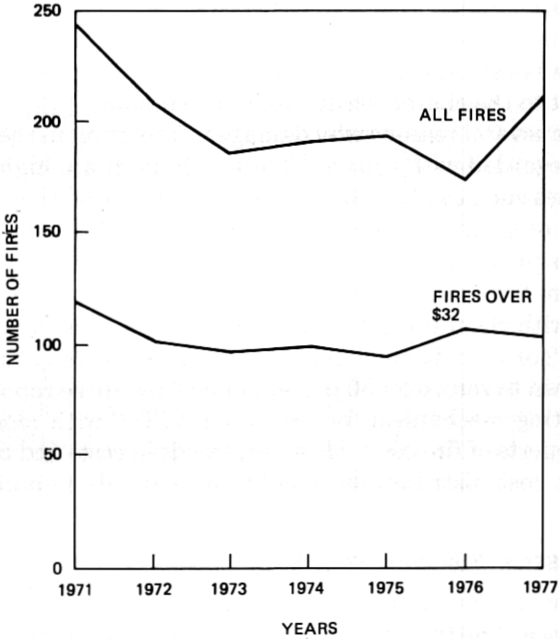


Fig. 1—Bell System building fire frequency, 1971–1977.

Even if inhomogeneities in the fire frequency had been revealed by the data, this would not necessarily have been reason for complacency or alarm. The Bell System continuously evolves in many ways; for example, the number of operating company employees and construction dollars have had year-to-year declines in the 1971–77 period. Furthermore, AT&T updated its fire protection policies and introduced fire-retardant materials in telephone equipment in the late 1960s; the benefits of these and similar actions have spread through the Bell System during the 1971–77 period. Changes in Bell System fire frequency, if they occur in the future, are likely to be complicated functions of many Bell System characteristics.

The important role played by small fires can be illustrated in another way. Counting C&P as one company, there are 19 operating companies plus Long Lines in the Bell System; it is a straightforward matter to calculate the expected number of fires for each of these in 1971–76 under the assumption that fires per million square feet per year are constant over the Bell System. One can then look at the likelihood of the actual counts, based on Poisson distributions having the expected counts as their means. It turns out that eight operating companies are in the upper 10-percent tail of the Poisson distribution (one at the 0.99999971 level), and six more are in the lower 10-percent tail of the Poisson distribution (one at the 0.0000002 level). However, if only fires greater than $32 are considered, most of this inhomogeneity vanishes; three companies lie in the upper 10-percent tail and four in the lower 10-percent tail (two companies should be in each tail because of normal statistical fluctuations). There is strong evidence of differential reporting of small fires among operating companies as well as for different years; fires which do significant damage (more than $32) are more reliably reported than small ones.

It is somewhat more meaningful to normalize Bell System fire frequency by relating it to floor area. The overall Bell System fire frequency is approximately 0.7 fires per million square feet of floor space per year. If the 15 percent of external (and roof) fires are removed from the total, the rate is reduced to 0.6. (However, if allowance is made for unreported fires as discussed above, the rate is increased to 0.85.) Although quantitative comparisons of this with other industries are hard to ascertain, one study by Factory Mutual Research[2] for the Naval Facilities Engineering Command divides properties on naval bases into three risk categories: less than 1 fire per million square feet per year (communications facilities, clinics, electronic data processing facilities, hospitals, outside storage, offices, child care centers, schools, vacant buildings, mobile equipment, warehouses), between 1 and 3 fires (aerospace manufacturing facilities, churches, cold storage plants, laundries, cafeterias, stores, theaters), and more than 3 fires (gasoline stations, barracks, clubs, laboratories, utilities and power plants, homes, recreational areas). To get a breakdown of Bell System fire frequency by type of space, it is useful to subdivide Bell System floor space into analogous categories. However, this task is hampered by the lack of centrally compiled statistics on Bell System occupancy. Based on rough estimates of Bell System floor areas (obtained, in the first three cases, by scaling up New Jersey Bell floor areas), the number of reported fires per million square feet per year is about 0.3 in switchrooms, 1.0 in power rooms, 0.2 in cable vaults, 0.5 in Community Dial Offices, and 1.0 in repeater huts and microwave stations.

2.2 *Probability density function of fire damage*

It is useful to summarize the Bell System data on fire damage by means of a probability density function characterized by a small number of parameters. Because of the extremely wide range of fire damage (most are a few hundred dollars or less, but fires exceeding $100,000 have occurred each year, and the Second Avenue fire in New York in 1975 was valued at $60 million), it is necessary to restrict oneself to probability density functions in which the independent variable is expressed in logarithms. Two common ones exist—the Weibull and the log normal; the latter turned out to fit the data quite well and is the one that was eventually selected.

Figure 2 shows the empirical cumulative distribution functions of fire damage for each of the seven years. (The totals do not agree with those in Section 2.1 because some fire reports omit damage estimates.) Because of the already-mentioned tendency of fire reports to round small-damage fires down to zero, only the upper half of the distribution (above the 50th percentile) is shown. The ith largest fire damage for a year having n fires is plotted at the point (x,y) corresponding to (log dollars, $1 - (i - 1)/n$); to avoid clutter, only the fires corresponding to $i = 1(1)\ 10(2)\ 20(5)\ 50(10)\ 100$ have actually been plotted.

In view of the noticeably greater variability of the data in the upper tail of the distribution, it was decided to fit a straight line to each cumulative distribution by a least-squares line fitted to the 50th, 60th, 70th, 80th, and 90th percentiles listed in Table III. (In this regression, the independent variables are the Gaussian deviates of the percentiles, and the dependent variables are the fire damages in log dollars.) After it was found that the slopes of the six lines did not significantly differ from each other, the model was reformulated: seven lines parallel to each other were fitted to the data instead. This was accomplished by reducing the 50th through 90th percentiles of the 1972 through 1977 data to the 1971 level by subtracting the average difference of the damage, as shown in the final column of Table III. The common value of the standard deviation (the slope) is 1.386 (in log dollars), and the median fire damage is given for each year in Table IV.

It is frequently useful to know the average fire damage as well. Because of the skewed nature of the log normal distribution, this is ordinarily a much larger value than the median. If m and s represent the mean and standard deviation of the log normal distribution in log dollars, the mean of the distribution in dollars is given by the formula:[3]

$$M = \exp(m \log_e 10 + (s \log_e 10)^2/2).$$

The values of M for the various years are also given in Table IV.

Why go through this involved procedure to calculate the average fire damage when an unbiased estimate of this quantity can be easily obtained by taking an average of the recorded fire costs? Unfortunately, the variance of such an estimate is quite large, for it depends almost entirely upon the values of the half-dozen largest fires in the set. The estimate M given above is based on m and s, which are far more representative of all the fires in the sample, not just those in the extreme tail.

It is likely that the observed differences in the median fire damages from one year to another are, at least in part, due to the inflation in repair costs over these years. To obtain an estimate of the percentage inflation rate, one can fit a straight line to the estimated median fire values (in log dollars), using the year as the independent variable. The slope of this

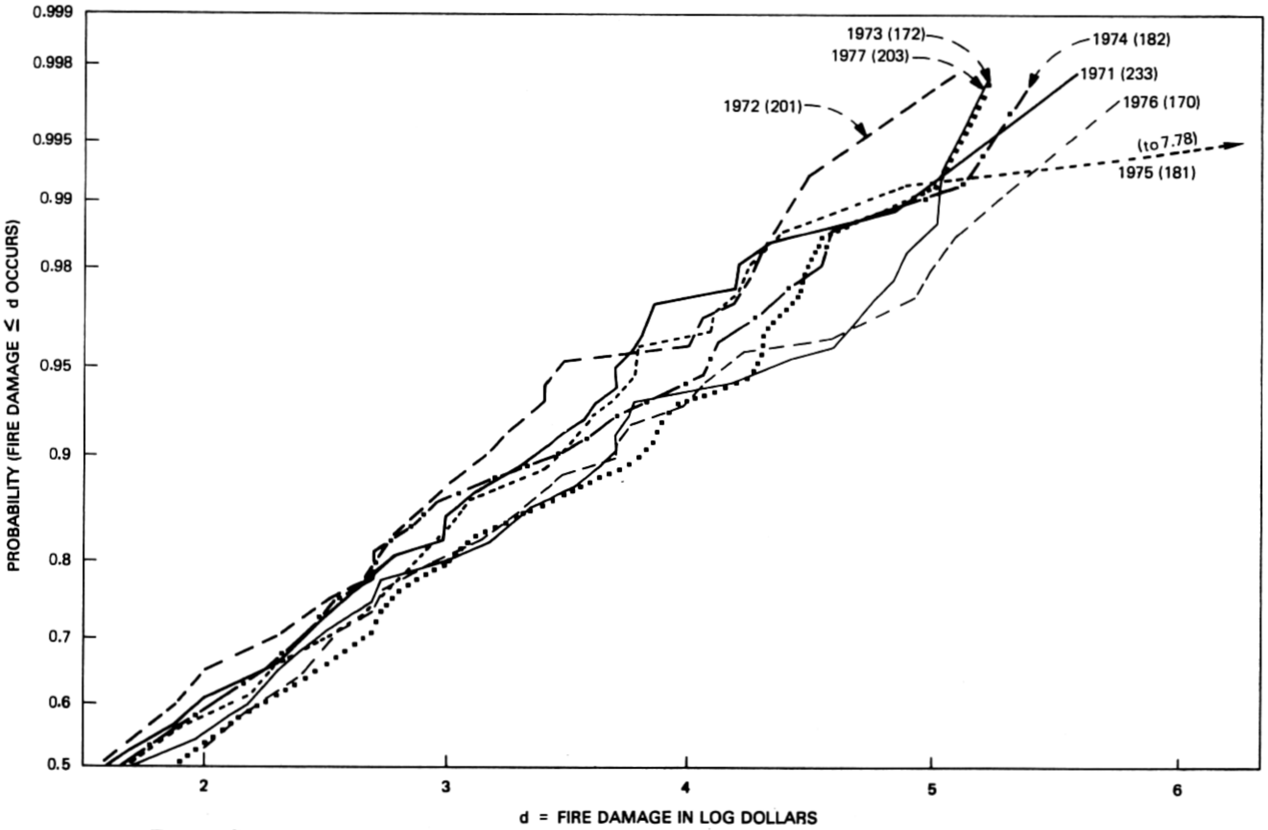


Fig. 2—Cumulative distribution function of fire damage, 1971–1977 (number of fires in parentheses).

Table III — Adjustment of fire damage (in log dollars) to 1971 level

	Percentile (Gaussian deviate)					
Year	50 (0.000)	60 (0.253)	70 (0.524)	80 (0.842)	90 (1.282)	
1971	1.54	2.00	2.40	2.72	3.37	
1972 original	1.59	1.88	2.30	2.70	3.18	
corrected	1.67	1.96	2.38	2.78	3.26	0.08
1973 original	1.86	2.18	2.69	3.00	3.79	
corrected	1.56	1.88	2.39	2.70	3.49	−0.30
1974 original	1.70	2.00	2.40	2.72	3.48	
corrected	1.65	1.95	2.35	2.67	3.43	−0.05
1975 original	1.65	2.10	2.42	2.88	3.43	
corrected	1.56	2.01	2.33	2.79	3.34	−0.09
1976 original	2.00	2.30	2.49	2.95	3.69	
corrected	1.72	2.02	2.21	2.67	3.41	−0.28
1977 original	1.70	2.18	2.48	3.01	3.70	
corrected	1.49	1.97	2.27	2.80	3.49	−0.21
Predict value	1.60	1.95	2.33	2.77	3.38	

Table IV — Median and average damage per fire for years 1971–1977

	Median	Average
1971	$40	$ 6481
1972	$33	$ 5390
1973	$79	$12931
1974	$45	$ 7272
1975	$50	$ 7973
1976	$76	$12349
1977	$65	$10511

fitted line is 0.04 in log dollars, or a rate of 10 percent per year, somewhat larger than the inflation rate corresponding to the well-known consumer price index from 1971 through 1977.

The 1975 New York fire, the most costly one in Bell System history, is not consistent with the log normal distribution. Its $60 million damage corresponds to a logarithmic cost of 7.778, which (after subtracting the average of the 1971–1977 median fire costs and dividing by the standard deviation) yields a standard normal variable equal to 4.37. This translates into a probability of only 0.0000062 that a fire randomly drawn from the log normal distribution will be this costly; if fires occur at the average rate of 200 per year, there is only a 50 percent chance that a fire this damaging will occur in 550 years corresponding to 1971–1977 experience: $(1–0.0000062)^{550(200)} = 0.506$.

Are there any other fires besides the New York one which are not consistent with the log normal distribution? Figure 3 depicts the 10 most costly fires in the Bell System during 1971–1977, compared with the 1971 log normal predicted line. To allow for inflation, all fires have been translated in damage values to hypothetical 1971 levels using the correction factors given in the final column of Table III. Clearly, the log-normal model fits all fires but the New York one reasonably well.

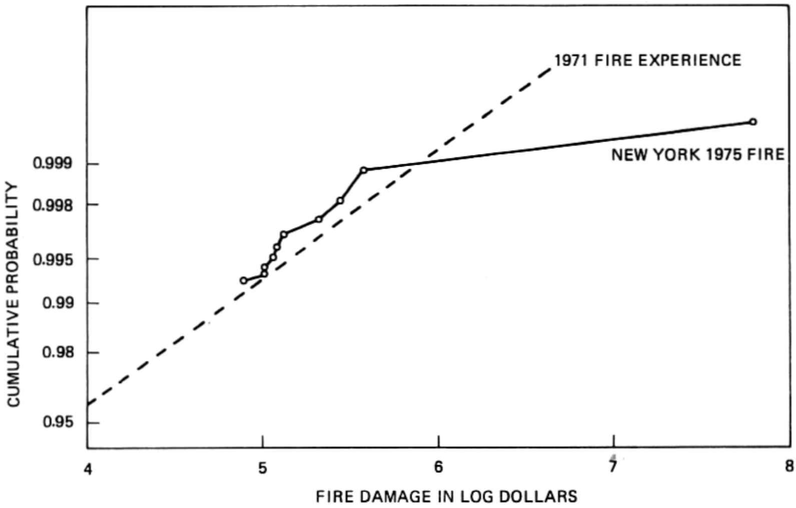


Fig. 3—Upper tail of fire damage distribution (10 most costly fires, 1971–1977).

Instead of believing that an event this unusual has occurred, the statistician prefers to conclude that the New York fire is a sample of one drawn from a probability density function of fire damage *different* from the ones shown in Fig. 2. With such a small sample, it is impossible to derive the distribution function of fire damage in the underlying population, nor is it easy to say what fraction of Bell System fires come from such a population. Although detailed statistics of the damage distribution of 3013 building fires during 1960–1970 are not available, the pattern of the most costly fires in that 11-year period ($1.67 million, $0.70 million, $0.50 million, $0.40 million, $0.19 million, $0.18 million, $0.15 million, $0.14 million, $0.12 million, . . .) is consistent with Fig. 2. Therefore, the fraction of building fires in the Bell System that do *not* follow this damage pattern is very small—one out of 3013 + 1483 = 4496 fires in 18 years! The best estimate of the fraction is 0.0002, and a 95-percent confidence interval enclosing the true but unknown fraction is (0.0000056, 0.00125).

It is hazardous to characterize the variability of the cumulative distribution function of fire damage based on only seven fitted lines, one for each year. The standard deviation of the difference between an observed percentile and its fitted value is approximately 0.07 in log dollars, for percentiles between 50 and 90. However, this is a misleadingly small number if one is interested in predicting the fire damage corresponding to a specified percentile of the cumulative distribution in a future year. As already noted, there is an increase of about 10 percent per year in fire costs, but the year-to-year fluctuation of the fitted lines around this 10-percent rate is considerable. For example, if one attempted to predict the fitted median fire damage of 1972 on the basis of the fitted median fire damage in 1971 with 10-percent inflation added, one would have overestimated by 0.12 in log dollars—inflation suggested an increase of 0.04, but in reality the 1972 fitted line was 0.08 below the 1971 one. Other year-to-year errors are even larger, and a rough estimate of the standard deviation of the error in estimating the following-year fit from the preceding-year one is 0.2 in log dollars. The standard deviation of the error in predicting an actual percentile in a future year is the root-mean-square sum of these two standard deviations, or again about 0.2 (since the smaller error is swamped by the larger). In dollars, this corresponds to a multiplicative factor of 1.6; thus, if one estimates a future fire damage to be (say) $1000, there is only a two-thirds chance that the actual fire damage will lie between $600 and $1600. If one is interested in predicting extreme percentiles, such as the damage of the largest fire to be expected in a future year, the errors are likely to be far larger.

2.3 Taxonomy of fires

Bell System building fires can be classified in a number of ways. Table V and Fig. 4 present a hierarchical classification in which fires are first sorted out by place of origin (under control of Bell System employees, or not under their control), then by fire type, and finally by the equipment in which it originated. Fire type is related to, but not identical with, the well-known classification of fires by fire extinguisher type: paper fires, electrical fires, oil and grease fires. A fire needs three things to ignite—oxygen, a fuel, and a source of heat; if the fuel is especially volatile, almost any source of heat will do the job, but if it is less volatile, the particular source is of greater concern. The following two-level description of fire type has been adopted:

- Fires with volatile fuels (oil, gas, gasoline, grease, etc.) regardless of heat source.
- Fires with less volatile fuels (paper, wood, insulation, etc.).
  - Electrical sparks or short circuits.
  - Overheating (placing a flammable substance too near a properly functioning heat-producing source, as a chimney or space heater).
  - Heat-generating tools (used too near flammable substances).
  - Smoking and matches (whether deliberately set or accidental).

Classification is not always as simple as this would suggest; for instance, electrical malfunction sometimes results in an overheated resistor which actually starts the fire (these fires have been classed as electrical). Note that fires in certain equipment can appear in several different places in Table V or Fig. 4. For example, a fire in a furnace will appear under Volatile (Fuel Oil) if this is involved; otherwise, it will appear under Electrical (Building Equipment, Furnace). Similarly, a fire in a stove can appear under Volatile (Grease), Overheating (Stoves), or Electrical

Table V — Explanation of fire taxonomy

- *External to Bell System:* earthquakes, lightning strokes, power wire crosses and surges, fires beginning on non-Bell property, water main breaks—but not fires caused by interruption of commercial power
- *Internal to Bell System*
  - *Volatile Fuels*
    - *Fuel Oil:* boiler explosions, fuel oil line leaks, oil in cans or on floor
    - *Gas:* explosions of gas furnaces, propane heaters, gas pipeline breaks
    - *Gasoline:* gas pumps, Bell System or employee vehicles located on Bell property—but not on assignment away from Bell property
    - *Tar Kettles:* contractor fires
    - *Hot Grease:* grease or fat associated with stoves and grills
    - *Other:* floor sealers, adhesives, calcium hypochlorite, windshield washing solvent, butane lighter, anti-static spray, oxygen tank, lacquer thinner, etc.
  - *Nonvolatile Fuels*
    - *Overheating*
      - *Furnaces, Heaters:* gloves on furnaces, cartons stored nearby—not including fires of volatiles
      - *Stoves:* papers in vicinity, coffee pot overheating, food bag in microwave oven—not including fires of volatiles
      - *Light Bulbs*
      - *Engine Exhaust:* ignition of building structure adjacent to emergency engine exhaust pipe
    - *Heat-Generating Tools:* acetylene and propane torches, soldering irons, grinding wheels, Cadwelders (including hot solder deposited in waste containers)—not including fires involving volatiles
    - *Smoking, Matches*
      - *Trash Containers:* ashtrays, wastebaskets, janitor carts and bags, scrap wire bags, rubbish rooms, trash compactors
      - *Loose Paper:* fires in paper or wood scraps not in trash containers (often regarded as due to arson)
      - *Mops, Cloths:* fires in janitorial closets caused by mops picking up smoldering cigarettes
      - *Chairs, Beds, Drapes:* fires in upholstered furniture in lounges or quiet rooms (often attributed to smoking)
      - *Cable Well Bags*
      - *Paper Records, Cartons:* a heterogeneous category including fires in paper supplies, books, bulletin boards, etc.
      - *Nonpaper Supplies:* fires in stored telephone supplies containing no obvious paper or cardboard (often regarded as arson, as ignition by cigarette is not easy)
    - *Outside Fires*
      - *Trash Containers:* truck-away containers in parking lots; piles of loose lumber or trash associated with construction activity
      - *Grass, Shrubs*
      - *Vehicles, Telephone Equipment:* night deposit boxes, cartons stored outside, employee cars, cable reels, plastic conduit (often regarded as arson)
      - *Construction Activity:* miscellaneous fires in construction areas not obviously associated with volatiles (tar kettles), trash piles or heat-producing tools (usually attributed to smoking)
      - *Construction Supplies, Roofing*
  - *Electrical*
    - *Building Power*
      - *Vaults, Transformers:* commercial power entrance facilities, including transformer vaults and entrance ducts
      - *Panels, Electrical Closets:* main commercial power switchboard, and branches terminating in panel boxes (wall-mounted, sometimes in separate closets)
      - *Local Wiring:* fires in distributive wiring of commercial power, including plugs in sockets—but not fires in appliances or known to be in fluorescent lights
    - *Building Appliances*
      - *Fluorescent Lights:* defective ballasts
      - *Local Air Conditioning:* window air conditioners or free-standing room units, humidifiers
      - *Heaters:* either portable or wall-mounted types
      - *Fans:* ceiling-mounted exhaust fans, pedestal fans, portable fans
    - *Building Equipment*

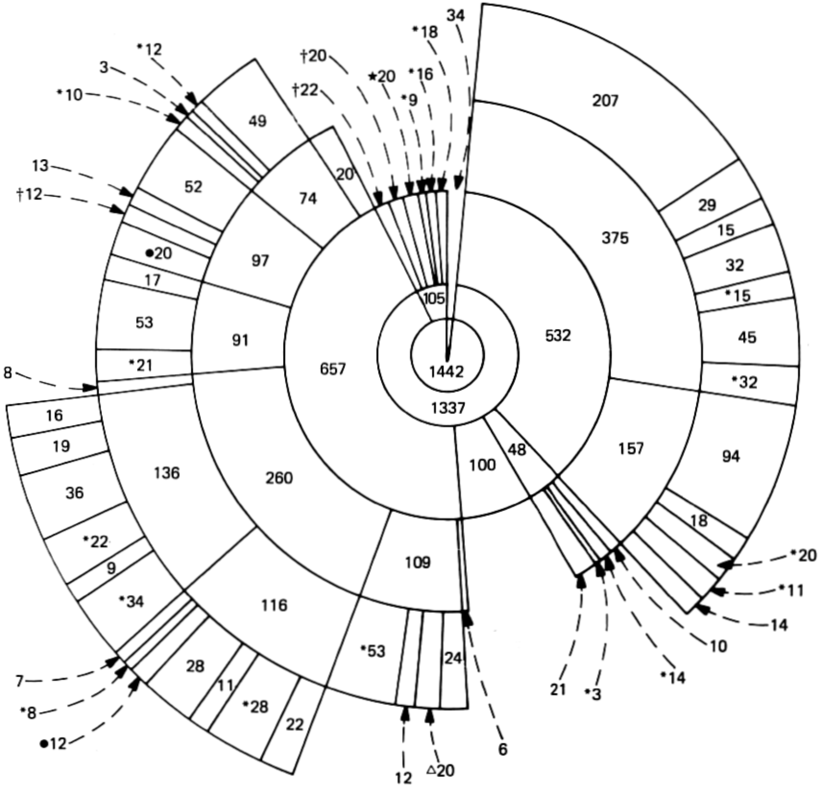
Table V (cont)

- *Central Air Conditioning:* fan motors, compressors, condensers, chilled water pumps
  - *Elevators:* motors, control circuits (including dumbwaiters)
  - *Furnace:* fires not obviously associated with volatiles, including mechanical failure also (belt leaving sheave)
  - *Other:* air dryers, vacuum pumps, motor controllers and control centers, ultrasonic cleaning machine, electric toilets, fire pump control cabinets, garage air compressors, portable battery chargers, sump pumps
- *Food Appliances:* coffee pots, stoves, portable defrosters, refrigerators and freezers, water coolers, sandwich and vending machines—not including fires attributed to volatiles or overheating
- *Office Appliances*
  - *Copiers:* fires in office copiers, including ones which are attributable to paper jams as well as electrical malfunction (source often difficult to determine from report)
  - *Computers, Calculators:* desk calculators, computer processing equipment
  - *Teletype:* those not directly associated with switching equipment
  - *Other:* offset press, envelope inserter, CRT service order machine, enclosing machine, assignment wheel, typewriter, conveyor belt motor
- *Automobiles:* fires not associated with gasoline
- *Telephone Equipment*
  - *Cable Vault:* fires in cabling (usually in open splices)
  - *Power Room Equipment*
    - *Emergency Engine:* load boxes, alternators, start motors, switches and related controls—not fires caused by overheating of exhaust duct
    - *Battery:* electrolytic leakage or cell overheating, and fires in associated circuitry
    - *Generator:* in motors or associated control circuitry
    - *Rectifier:* includes converter and inverter fires
    - *Power Plant:* fires in 130-volt power panels, or in general power controls such as the 412B power plant or Uninterrupted Power Source equipment
    - *Cabling:* principally in DC power cables, and often due to craftsman error
  - *Switchroom Equipment*
    - *Main Distributing Frame:* usually fires in open splices
    - *Test and Operator Boards*
    - *ESS Switchers:* includes TSPS, and closely associated equipment such as teletypewriters
    - *Carrier:* primarily N and T carrier, and often in unattended remote locations
    - *Radio:* includes mobile radio, and often in unattended remote locations
    - *EM Switchers:* includes closely associated equipment such as teletypewriters; fires usually in relays, markers, fuses, step-by-step switches, line finders, etc.
    - *Other:* fires in auxiliary equipment, and incompletely identified switchroom fires (most of these probably associated with EM switching)

(Food Appliances), depending upon the nature of the fire. Note also that this taxonomy cannot be used to determine the number of fires that occur in a given type of Bell System space (switchroom, power room, utility room, cafeteria, hall, etc.); in general, a wide variety of different fires can occur in a given location.

In Table V and Fig. 4, 67 building fires occurring in Bell Canada from 1971 through 1974 are also included to provide as large a statistical base as possible.

Figure 4 depicts the relative frequency of different types of Bell System building fires. The relative seriousness of these different types is presented in Figs. 5 and 6, in which the damage of each fire type is plotted (on triangular graph paper) according to a trinomial probability density



3	TELETYPE
*3	LIGHT BULBS
6	AUTOMOBILES
7	M. D. FRAME
8	CABLE VAULT
*8	TEST, OPERATOR
9	POWER PLANT
*9	TAR
10	FURNACES
*10	OTHER
11	RADIO
*11	CONSTRUCT. ACT.
12	FURNACES
*12	COMPUTERS
†12	HEATERS
●12	ESS
13	LOCAL AIR COND.
14	CONSTRUCT. SUPP.
*14	STOVES
15	MOPS, CLOTHS
*15	CABLE WELL BAGS
16	EMERGENCY ENGINE
*16	GREASE
17	VAULTS, TRANSFORMERS
18	GRASS, SHRUBS
*18	OTHER
19	BATTERIES
20	FOOD APPLIANCES
*20	TELCO EQUIP.
†20	GAS
●20	PORTABLE FANS
★20	GASOLINE
△20	ELEVATORS
21	ENG. EXHAUST
*21	LOCAL WIRING
22	OTHER
*22	RECTIFIERS
†22	FUEL OIL
24	OTHER
28	CARRIER
*28	ELECTRO-MECHANICAL
29	LOOSE PAPER
32	CHAIRS, BEDS, DRAPES
*32	NON-PAPER SUPPLIES
34	EXTERNAL
*34	CABLING
36	GENERATORS
45	PAPER RECORDS, CARTONS
48	OVERHEATING
49	COPIERS
52	FLUORESCENT LIGHTS
53	PANELS, ELECTRICAL CLOSETS
*53	CENTRAL AIR CONDITIONING
74	OFFICE APPLIANCES
91	BUILDING POWER
94	TRASH
97	BUILDING APPLIANCES
100	HEAT GENERATING TOOLS
105	VOLATILE
109	BUILDING EQUIPMENT
116	SWITCHROOM
136	POWER ROOM
157	OUTSIDE
207	TRASH IN CONTAINERS
260	TELEPHONE EQUIPMENT
375	INSIDE
532	SMOKING, MATCHES
657	ELECTRICAL
1337	HEAT SOURCES
1442	INTERNAL

Fig. 4—A taxonomy of Bell System building fires, 1971–1977 (1476 total, including Bell Canada, 1971–1974).

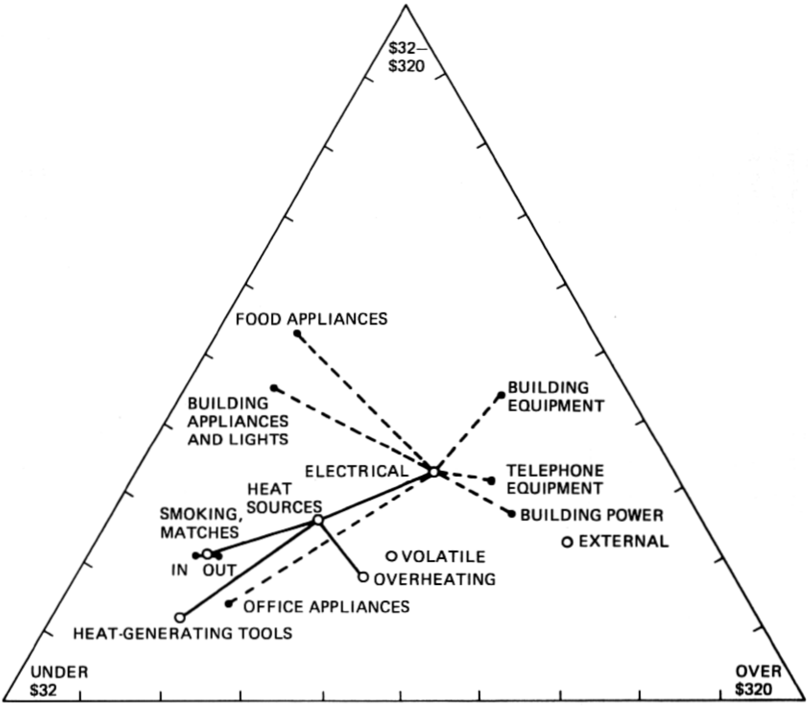


Fig. 5—A trinomial distribution of fire damage.

function: the fraction of fires less than $32, the fraction of fires between $32 and $320, and the fraction of fires above $320. (These limits were selected because they divide all Bell System building fires into approximately equal parts.) Thus, points plotted near the lower left corner of Fig. 5 or 6 correspond to fires with typical damage under $32, and points plotted near the lower right corner, to fires with typical damage over $320.

By using Figs. 4, 5, and 6 in concert, one can learn a great deal about the impact of different fires upon the Bell System. For example, inside trash container fires are relatively common (207 fires in seven years), but rarely cause much damage (73 percent under $32); on the other hand, battery fires are considerably rarer (19 fires in 7 years) but are far more costly when they do occur (53 percent over $320).

If fire frequencies are examined year by year for each of the categories in the taxonomy, few patterns of interest emerge. However, the decline in fires related to construction and installation activity is noteworthy. Although overall construction dollars discounted for inflation have remained in a narrow range from 1971 through 1977 ($5.6 to $6.8 billion, in 1967 terms), construction-related fires have declined in every year, from 44 in 1971 to 7 in 1977. The four most relevant categories are listed in Table VI.

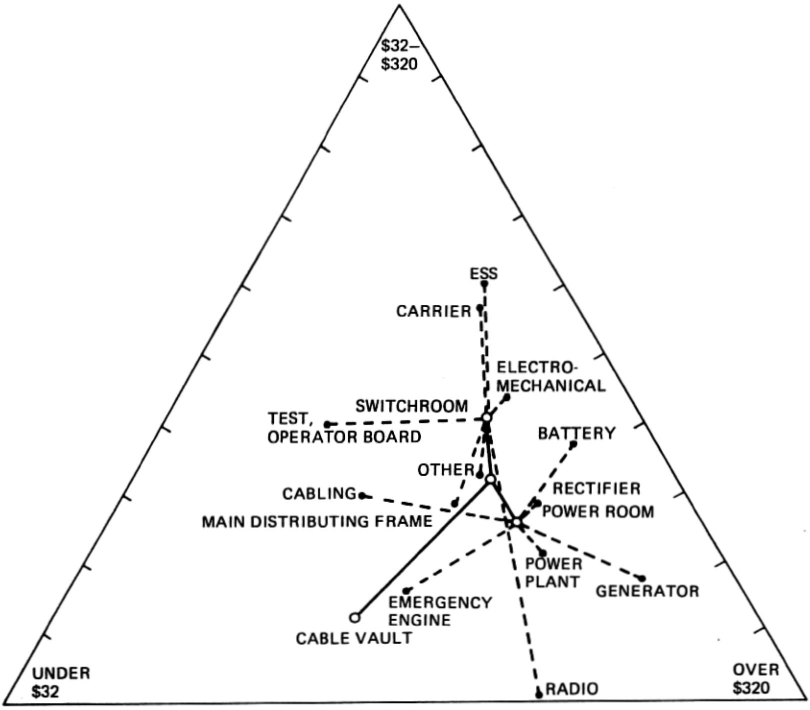


Fig. 6—A trinomial distribution of telephone equipment fire damage.

Table VI — Decline in fires related to construction activity

	1971	1972	1973	1974	1975	1976	1977
Outside fires (construction activity)	6	1	3	0	0	1	0
Outside fires (construction material)	6	3	2	2	0	1	0
Heat-generating tools	24	20	18	15	10	8	5
Power room equipment (cabling)	8	12	2	2	5	3	2
Total	44	36	25	19	15	13	7

III. SPECIAL STUDIES OF BUILDING FIRES

This section of the paper shows how the information on the fire report form can be used to carry out various studies involving specific aspects of Bell System building fires. In particular, four topics are introduced: (*i*) an analysis of employee injuries and service interruptions caused by fires, (*ii*) the correlation of business hours with fire frequency and the correlation of building occupancy with fire severity, (*iii*) the methods employed in fighting Bell System building fires, and (*iv*) an analysis of correlated fire events in buildings, and the cluster of fires in the New York City area in March 1975. These topics are meant to be illustrative rather than exhaustive; others could easily be developed.

3.1 Definitions of fire damage

Dollar loss is, perhaps, the most well-known definition of fire damage, but it is not the whole story. In the Bell System, two other measures may also be appropriate:

(*i*) With the strong Bell System emphasis on safety on the job, it is of interest to study injuries to employees occurring as the result of fires.

(*ii*) With the strong Bell System emphasis on reliable service to the customer, it is of interest to study service interruptions occurring as the result of fires.

Of the 1483 fires between 1971 and 1977 (including Bell Canada) for which reports were filed, one fire resulted in the death of a contract (non-Bell) worker servicing an air-conditioning system and the injury of three Bell System employees, and 19 other fires resulted in the injury of a total of 5 contract workers and 16 Bell System employees. There are several possible reasons for the relatively high injury rate of contract employees: They may typically work with more volatile substances (eight of the fires, including four of the five fires involving contract personnel, were characterized by explosive ignition of highly volatile liquids or gases), and they are less likely to be well-instructed in safe working procedures and well-motivated to follow them than Bell employees.

These injury statistics can be put in broader perspective by comparing them with the 1976 estimates of fire injuries and deaths throughout the United States prepared by the National Fire Protection Association.[4] There were 2.94 million fires in the United States resulting in 108,000 injuries and 8,800 deaths; if Bell System fire experience was comparable, the 1483 reported fires would have resulted in 55 injuries (instead of 24) and 4.5 deaths (instead of 1). Looking at the data from a different perspective, 600,000 operating company and contract employees working 8 hours per day, 5 days per week, have 1/1470 of the potential exposure to fire of 210,000,000 United States residents living 24 hours per day, and therefore should incur 73 injuries and 6 deaths per year (instead of 3.4 and 0.1, respectively). Even though the environment and characteristics of United States residents and Bell employees are markedly different, it is clear that the Bell System has an excellent safety record with respect to fires when they do occur.

Service interruptions due to building fires, although rare, are slightly more frequent than injuries. Interruptions can broadly be divided into two classes:

(*i*) Fires that destroy interoffice trunk circuits resulting in possible delays caused by increased congestion on alternate routes.

(*ii*) Fires that deny service to individual telephones.

It can be argued that the latter loss is of much greater importance to the Bell System; as long as the delays are not large, subscribers may not even be aware of the former impediment.

Clearly, some buildings are more likely than others to be the site of fires resulting in service impairment; garages and office buildings have little or no likelihood of this. More specifically, some areas of a central office are more vulnerable than others to service-impairing fires—the areas of greatest risk are those containing individual subscriber lines (cable vault, main distributing frame, first stage of switcher) or those which contain unduplicated equipment.

If a fire denies service to individual telephones, a rough measure of its impact is the number of days of lost service multiplied by the number of exchanges affected, called exchange-days for brevity. (An exchange can contain up to 10,000 lines, not including extension telephones or PBXs, but the number of assigned lines in a typical exchange will be considerably less.) Fire reports do not call for information on service interruption, so that more precise measures than exchange-days are hard to calculate; often, this is only a rough estimate. Table VII lists the most serious service-impairing fires (as measured by exchange-days) encountered between 1971 and 1977. In addition to the 22 fires in this table, 20 more fires affected trunks, principally carrier and radio circuits, for various lengths of time.

3.2 Some relationships between fires and people

Two truisms associated with fires are: (*i*) fires are at least in part caused by human activity, and consequently are more frequent during those hours that a building is occupied, and (*ii*) fires are less costly if they can be detected and fought quickly. Thus, one expects a few costly fires at night or on weekends (or at unattended buildings, such as Community Dial Offices or repeaters), and numerous but inexpensive fires at attended buildings during business hours. To what extent do the data support these truisms?

Table VIII shows there is a mild (but statistically significant at the 0.002 probability level, using a chi-squared test of goodness of fit)

Table VII—Building fires which impaired service to individual subscribers 1971–1977

Feb 27, 1975	New York, N.Y.	270 exchange-days
Nov 10, 1971	New York, N.Y.	1.5 exchange-days
Feb 11, 1971	Long Island City, N.Y.	1.0 exchange-days
May 19, 1973	Peekskill, N.Y.	0.5 exchange-days

In addition, there were 18 fires in operating companies which resulted in less than 0.1 exchange-days of service impairment.

Table VIII — Frequency of building fires by month

January	116	April	139	July	133	October	132
February	134	May	116	August	147	November	99
March	144	June	105	September	112	December	114

Table IX — Frequency of building fires by day of week

Saturday	122	Monday	236	Thursday	282
Sunday	96	Tuesday	240	Friday	253
		Wednesday	252		

seasonality to fires, with maxima in March and August and minima in June and November. Table IX demonstrates that there is a strong difference in fire incidence between business days and weekends; weekend fires occur less than half as frequently. However, there are no statistically significant differences among the different weekdays. Finally, Table X and Fig. 7 exhibit a strong relationship between fire frequency and the time of day, with a minimum around 5 a.m. and a broad maximum around noon. Note that the fire incidence rises steeply in the morning, but falls off much more gradually at night. This function follows fairly closely the number of on-premise employees (including contract labor), with a delay factor to allow for the fact that a certain number of fires smolder awhile before being discovered.

Table X — Time of day of discovery of building fires

Night and Morning				Afternoon and Evening			
12–1	30	6–7	30	12–1	97	6–7	74
1–2	24	7–8	47	1–2	98	7–8	56
2–3	26	8–9	77	2–3	102	8–9	55
3–4	24	9–10	100	3–4	84	9–10	52
4–5	16	10–11	96	4–5	108	10–11	43
5–6	23	11–12	105	5–6	70	11–12	37

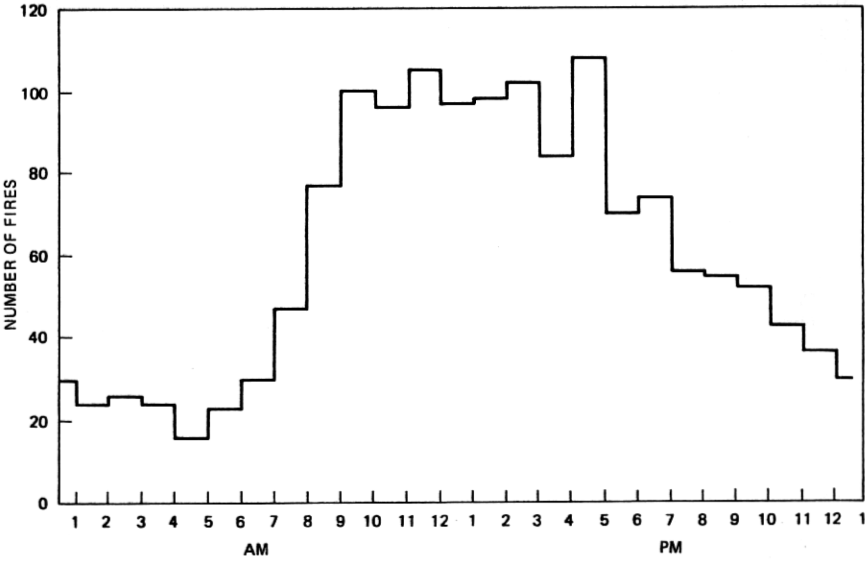


Fig. 7—Frequency of fires as function of time of day.

From 1971 through 1977 (Bell Canada fires 1971–1974 only), a total of 159 fires occurred in buildings unoccupied at the time the fire broke out. Of these, 44 fires self-extinguished, 4 were put out by sprinker systems, and 1 by a Halon system. (In one of the remaining fires, a sprinkler system inside the building was activated by the heat of an external fire, but it played no role in putting the fire out.) Fitting a log probability density function by a least-squares line as described in Section 2.2 (to the 50, 60, 70, 80, 90, and 95 percentiles) the estimated median fire damage turns out to be 2.88 ($630), and the slope is 1.316 (in log dollars). In other words, the median damage of a fire in an unoccupied building is approximately 10 times as large as the median damage of a fire in an occupied building. Put another way, out of the 26 Bell System fires of at least $50,000 damage, 15 were in unoccupied buildings; this supports the statement that about half the Bell System building fire damage occurs in unoccupied buildings.

Although Tables IX and X strongly suggest that fires occur less often in unoccupied buildings than occupied ones, it is difficult to establish a causal relationship. Telephone demand (and hence electrical activity in telephone central offices) also reduces at night and on weekends; could this result in fewer telephone equipment fires and building power fires as well, regardless of the number of people present? Furthermore, it is impossible to estimate the average number of fires per million square feet of unoccupied space per year unless one knows the areas of Bell System buildings as a function of their occupancy: $f(x)$ square feet occupied x or more hours per week, for $0 \le x \le 168$. Unfortunately, these data are not available from the operating companies, and it would take a substantial effort to generate $f(x)$ for the 20,000 or more buildings in the Bell System. If $f(x)$ were known, it might be possible to predict the effect (with respect to fire) of such actions as dispersing Bell System switching equipment into a large number of small unmanned central offices close to the subscriber instead of a few larger central offices at a greater distance.

It would be desirable to extend this study to see if there is any difference in fire severity as a function of the distance to the nearest person in occupied buildings. Unfortunately, the fire report form does not give such information; however, the crude analysis given in Table XI may be suggestive. These figures should be interpreted with considerable caution, because the mixture of fires may not be the same; for example, fires detected by electrical means are likely to be expensive equipment fires, whereas fires detected by smoke or odor are likely to include a large number of inexpensive trash fires in addition to equipment fires. Thus, the fact that the median damage for fires detected by equipment or smoke alarms is greater than the median damage of fires detected by heat or odor should not be regarded as a demonstration of ineffectiveness of the former.

Table XI — Median fire damage in occupied buildings 1971–1975

	Number of Fires	Median Damage (Dollars)
People in other room, fire detected by equipment or smoke alarm	92	200
People in other room, fire detected by odor, noise, or light	205	30
People enter room in which fire is located (for other reasons)	154	20
People already in same room as fire	320	10

3.3 Methods used to fight building fires

During the 1971–76 period, Bell System regular or contract employees took action with respect to 1088 fires, either by fighting it themselves, calling the fire department, or both; this represents 86 percent of all building fires that occurred in that period. Fires in which employees were not involved are of two types: (*i*) those detected by outsiders who called the fire or police department or who (in one instance) extinguished the fire themselves, (*ii*) those detected by telephone people which were already out, or which self-extinguished before any action was taken (and the fire department was not notified).

Table XII shows that certain occupational groups—inside craft and, to a lesser extent, office worker and building mechanic—are the ones most likely to deal with Bell System building fires. Inside craft includes occupational titles such as switchmen, powermen, splicers, combinationmen, test deskmen, framemen, and central office maintenance; office workers include clerks, stockmen, cafeteria workers, service representatives, engineers, and other white-collar occupations, including management above supervision; building mechanics include titles such as building engineers, watch engineers, building maintenancemen, elevator mechanics, building electricians, and building technicians. Note that three occupations—construction, janitor, and guard—are likely to include substantial numbers of contract employees. The occupation was not specified in 12 percent of building fires.

Fires can be fought in many different ways, and these are summarized in Table XIII. Informal methods ordinarily involve blowing out or

Table XII — Distribution of Bell System occupations fighting fires

Occupation	Fraction of Fires
Auto mechanic	0.02
Janitor	0.06
Office worker	0.14
Inside craft	0.41
Operator	0.03
Guard	0.04
Western Electric	0.04
Construction	0.08
Install/repair	0.04
Building mechanic	0.14

Table XIII — Fraction of fires in which various fire-fighting methods were used

	Not Call	Fire Department Call, not Need	Call and Need
Informal methods	0.16	0.05	0.01
Extinguisher or hose	0.42	0.14	0.07
Call fire department only	–	0.03	0.12

smothering the fire, throwing a glass (or a pail) of water on it, or turning off the electricity. The fire department was considered to be called and needed if they played a significant role in putting out the fire; if the fire was out (or almost out) when they arrived, and they assisted only in clean-up or smoke evacuation, they were considered to be called but not needed. A substantial fraction of fires are put out with the aid of an extinguisher and no notification of the fire department; in only 20 percent of all fires was the fire department really necessary. These fractions remain much the same for paper fires or electrical fires, but volatile fires are less likely to be fought using informal methods without notifying the fire department (0.04 instead of 0.16), and more likely to involve extinguishers combined with an unneeded fire department (0.21 instead of 0.14) or a call to the fire department with no attempt to fight the fire (0.24 instead of 0.15).

Bell fire-fighters using extinguishers or hoses almost always select the proper tools for the job; in only 13 cases was water apparently used (in whole or in part) on an electrical or a volatile fire. On the other hand, it is worth noting that women are infrequent users of extinguishers or hoses; out of 682 fires in which these tools were used, only 18 (about 2.6 percent) involved women.

Figs. 8, 9, and 10 (all plotted on triangular graph paper) give a more detailed look at the different fire-fighting exposures and techniques encountered by various occupations. Not surprisingly, auto mechanics and (to a lesser extent) installation and repair personnel (based at garages) encounter far higher percentages of volatile fires than the other groups; inside craft and Western Electric encounter more electrical fires than others, whereas janitors and (to a lesser extent) office workers, construction workers, and guards encounter paper fires. Operators and guards are far more likely to call the fire department than fight the fire, but inside craft, Western Electric and (to a lesser extent) construction workers, janitors, and building mechanics are unlikely to do so. Fires encountered by automobile mechanics, guards, or installation and repair personnel are the most likely to require professional assistance; fires associated with Western Electric or inside craft, the least.

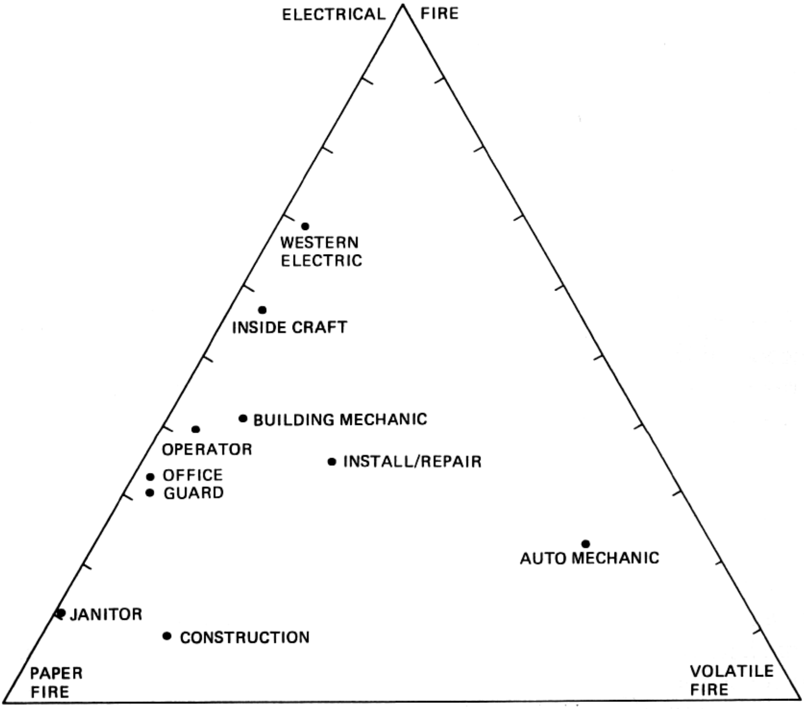


Fig. 8—Occupational exposure to fighting paper-electrical-volatile fires.

3.4 Correlated fire events

Many Bell System buildings have had more than one fire in the 1971–76 time period; in fact, one building has had 10. Statistical methods can be used to assess multiple fire events, to determine whether they are attributable to statistical fluctuations of fires occurring independently and at random, or to correlated events between fires. Correlated fires can arise for various reasons; the most common one is arson, but an undiagnosed electrical fault can lead to repeated occurrences of fire as well.

There are two distinct ways in which the possible correlation between fires at a given building can be examined. First, if x fires have been observed, one can ask if they cluster in a small period of time, rather than spreading out over the entire period. Second, one can ask whether x fires is excessive for that building, given Bell System fire experience. This is a somewhat more difficult assessment, for one must decide how to normalize the building with respect to the Bell System. Floor area is the most plausible candidate, but in view of the relationship between fires and people exhibited in Section 3.2, the number of people in the building may be a better normalization. In any event, one must be quite cautious in deciding whether or not a given Bell System building is more fire-prone

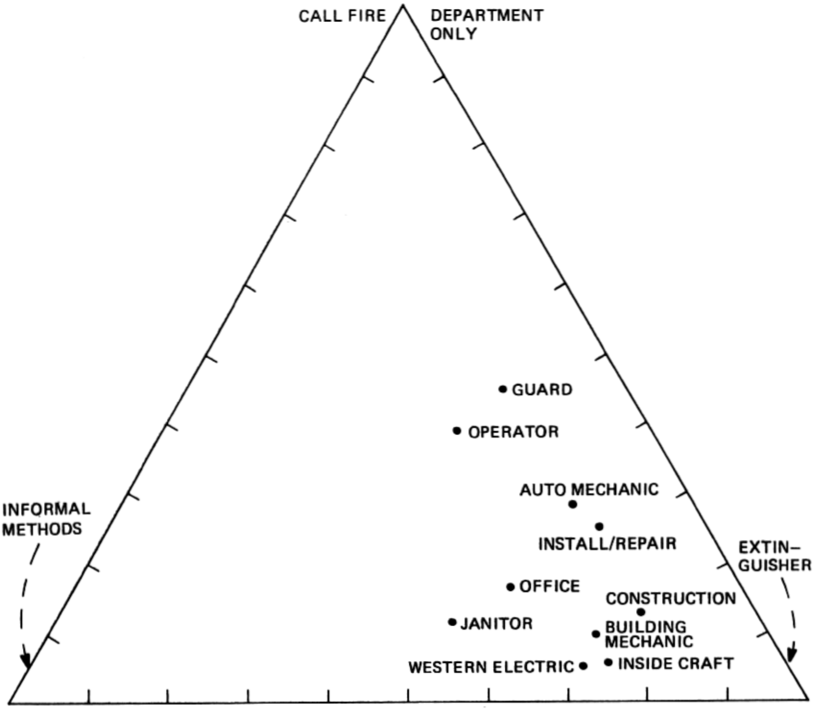


Fig. 9—Fire-fighting techniques used by various occupations.

than others, simply on the basis of a larger-than-average number of fires.

If x fires have occurred in a building, the cumulative probability density function of the smallest time-spacing between any two consecutive fires can be written[5]

$$\text{Prob(minimum spacing} \leq t) = 1 - (1 - (n - 1)t)^n,$$

where n is the total number of fires and t is normalized with respect to the total time-interval (for example, if two fires occur 10 days apart in a 6-year period, t is equal to 10/2192, or 0.00456). If fires occur independently, and at random at a building throughout the time interval, this probability is distributed uniformly between zero and one; on the other hand, if there is correlation between fires (the occurrence of a fire raises the chance of another fire occurring in the near future), then there will be an excessive number of small values of the probability. Table XIV summarizes the probabilities associated with all multiple-fire buildings. The right-hand column clearly indicates that there are more buildings with small probabilities than with large ones; a chi-squared test of goodness-of-fit confirms that this result is not explainable by random fluctuation (at the 0.0000001 level).

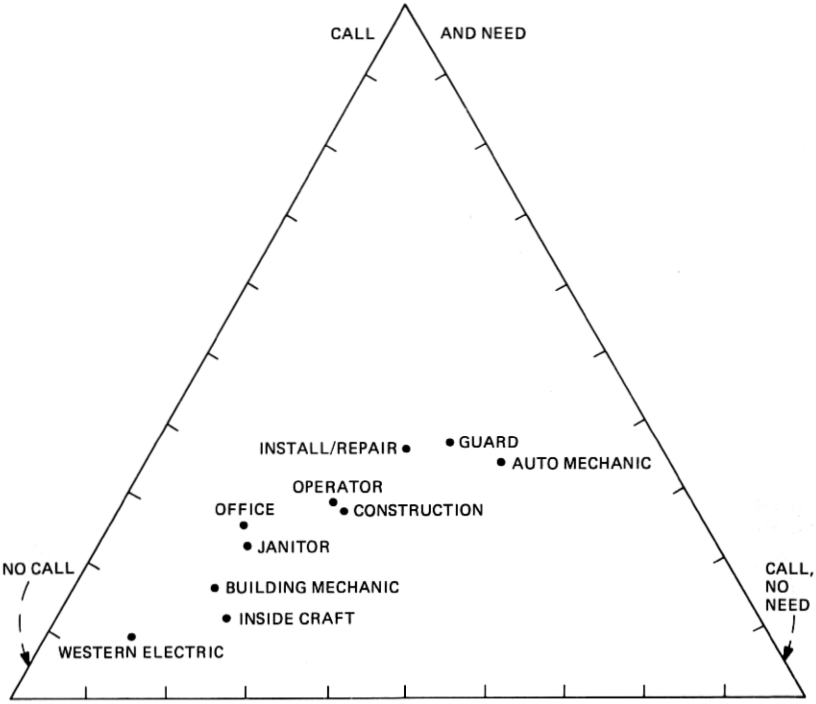


Fig. 10—Propensity of various occupations to call fire department.

Table XIV — Distribution of minimum time-interval probabilities for Bell System buildings with two or more fires, 1971–1976

Probability (minimum spacing ≤t)	Number of Buildings
0–0.1	44 (17)
0.1–0.2	26 (21)
0.2–0.3	17 (15)
0.3–0.4	17
0.4–0.5	10
0.5–0.6	15
0.6–0.7	8
0.7–0.8	8
0.8–0.9	10
0.9–1.0	9
	164 (130)

However, the inflation in probabilities does not extend beyond 0.3, for a similar chi-squared test on the last seven values yields a value of only 6.91, significant at the 0.3 level.

If one examines the fire reports for those 87 buildings for which the probabilities are less than 0.3, it is not hard to identify pairs of fires that appear to have some common factor. If these 34 buildings (20 percent of all multiple-fire buildings) are subtracted from the total, the parenthesized values in Table XIV result, and the corresponding chi-squared test of goodness-of-fit is far more plausible under the hypothesis of randomness and independence: it is 14.46, significant at the 0.11 level. In other words, it is possible to detect most, if not all, of the correlation in multi-fire buildings by a reading of the fire reports; there does not appear to be much additional correlation present.

Most of the correlated events in the 34 buildings removed from the analysis are arsonous in nature; only six appeared to have other causes:

(*i*) A fire in the power panel of the turbine room of one building occurred within 10 minutes of a fire in the turbine sensing unit in a neighboring building.

(*ii*) Two fires 14 days apart occurred in the AC busway serving an ESS office.

(*iii*) An electrical fire in aisle 31 on the third floor of a mobile radio center was followed 98 days later by an electrical fire in aisle 32 on the same floor.

(*iv*) Two fires 26 days apart were caused by careless use of a cutting torch during modification of a building by a contractor.

(*v*) A fire in a coffee urn in a ladies' lounge was followed by a fire in a stove in the same lounge 10 days later.

(*vi*) A fire in a 48-volt generator in a power room was followed 21 days later by a fire in a 24-volt generator in the same room.

Unfortunately, this statistical technique cannot be used to identify arson in Bell System buildings if the arsonist acts only once; many such fires can be effectively made to look like accidents (for example, a cigarette carelessly thrown into a wastebasket). It is only when the arsonist strikes twice within a reasonably short period of time (say, six months) that his presence is almost always suspected.

In principle, a similar statistical analysis could be performed on the number of fires in each building in the Bell System normalized with respect to floor area (or other indicator of size or activity); however, floor area data on the 20,000 or more buildings in the Bell System is widely dispersed and not readily available for analysis. To give some flavor of the possible calculations, Table XV presents statistics on all buildings in the Bell System having eight fires or more during 1971–1976. The

Table XV — Buildings in the Bell System with eight or more fires, 1971–1976

	Floor Area (thous. sq. ft.)	Obs. Fires	Exp. Fires	Pr(fires ≥ observed)
Fresno, Cal.	179	10	0.76	0.00000001
Detroit, Mich.	769	9	3.25	0.0063
Manhattan, N.Y.	516	8	2.18	0.0019
Bronx, N.Y.	328	8	1.39	0.00010
Washington, D.C.	167	8	0.71	0.0000008
Bell System: 1194 fires, floor area 282.1 million sq. ft.				

expected number of fires in Table XV is calculated by multiplying the total fires in the Bell System by the ratio of the building floor area to the Bell System floor area; the probability of observing this number of fires or more, given the expected number, is calculated by means of the Poisson probability density function

$$\Pr(x \text{ or more fires}) = \sum_{i=x}^{\infty} \exp(-\lambda)\lambda^i/i!.$$

In four of these buildings, a reading of the fire reports clearly points to an arsonist at work. The fifth building, in Detroit, has no obvious pattern of fires, but it is likely that an event of probability 0.0063 could have occurred by chance, given the large number of Bell System buildings. (In a list of 20,000 buildings, there is a 50-50 chance that the probability in the final column of Table XV will be less than 0.000025 in at least one case, even assuming all the buildings have the same underlying fire propensity per square foot. To assess the correctness of this assumption, one would have to look at the probabilities associated with *all* of the buildings.) Furthermore, the minimum spacing between any pair of fires in the Detroit building (12 days) is not unusual; a random sample of 9 fires will produce a shorter minimum spacing 33 percent of the time.

The typical fire in the Bell System receives very little publicity; usually, only a few of the workers in the building know about it. (Since 58 percent of all fires do not involve the fire department, newspaper coverage is likely to be sparse.) It is of interest, therefore, to assess the impact of a Bell System fire which generated enormous publicity in a metropolitan area—the February 27, 1975 fire at 204 Second Avenue in Manhattan. Among other things, newspapers reported a rash of fires in other telephone buildings in the area during the month that repairs were being made; it was suggested that the fire publicity might have encouraged latent arsonists elsewhere in New York Telephone Company.

One can examine the fire data to see whether or not such an allegation is true, or whether the number of fires that occurred in the next month can be explained as a not-untypical fluctuation in the pattern of fires over the entire seven years. Table XVI gives the number of months (out of 84) in which 0, 1, 2, $\cdots$ fires were observed in Manhattan, in all five boroughs of New York, and in the Greater New York metropolitan area (specifically, all fires in the five boroughs, in the Nassau and Westchester operating areas of New York, and in the Essex, Raritan, and Hudson operating areas of New Jersey). The "Obs" column gives the actual number of months that the indicated number of fires were observed, and the "Poi" column gives the expected number of fires if a Poisson probability density function is fitted to the data

The one-parameter Poisson distribution does not fit the data particularly well; in fact, a chi-squared test of goodness-of-fit rejects the model

Table XVI—Distribution of number of fires by months, 1971–1977, in the Greater New York area

	Number of Months with Indicated Fires in								
	Manhattan			5 Boroughs			Greater N.Y.		
Fires	Obs	Poi	NB	Obs	Poi	NB	Obs	Poi	NB
0	44	37.8	41.0	26	19.7	22.8	15	9.2	12.9
1	20	30.2	26.5	23	28.5	26.8	17	20.3	20.6
2	13	12.0	11.1	13	20.7	18.3	23	22.5	19.4
3	7	3.2	3.8	17	10.0	9.5	8	16.6	13.9
4				3	3.6	4.1	12	9.2	8.5
5				2	1.1	1.6	4	4.1	4.6
6							4	1.5	2.3
7							1	0.5	1.1
m		0.80			1.45			2.21	
s^2		0.98			1.79			3.06	
r		3.44			6.19			5.78	
c		4.31			4.27			2.61	

at probability level of 0.03, 0.04, and 0.06, respectively. There is some evidence that fires tend to cluster in months more than a Poisson model would predict; note that the number of months with zero fires or with a large number of fires generally exceeds expectations. In such a situation, the two-parameter negative binomial distribution (also known as the Polya distribution, and often used in studies of accident-proneness) provides a better fit to the data. In the negative binomial, it is assumed that m, the mean of the Poisson distribution, is itself distributed according to the gamma distribution $c^r m^{r-1} \exp(-cm)/\Gamma(r)$. The probability of 0, 1, 2, 3, $\cdots$ observations in a cell is given by the successive terms of the series

$$\left(\frac{c}{c+1}\right)^r \left[1, \frac{r}{c+1}, \frac{r(r+1)}{2!(c+1)^2}, \frac{r(r+1)(r+2)}{3!(c+1)^3}, \cdots\right],$$

where c and r are estimated from the mean and variance of the data by the formulas

$$c = m/(s^2 - m), r = cm.$$

The negative binomial fit to the data is given in the "NB" column of Table XVI; the fit is considerably improved.

As far as fire reports are concerned, March 1975 (the month following the Second Avenue fire) witnessed three fires in Manhattan, one in Queens, and one in the suburbs. (These numbers do not tally exactly with newspaper-reported fires for several reasons: One Manhattan building fire inexplicably failed to generate a fire report, and a couple of fires occurred on customer premises or in outside plant, which are not covered by the fire report; on the other hand, one fire included here was not reported to the fire department and did not appear in the papers.) Using the Poisson model, the estimated probability of three or more fires in

Manhattan in one month is 0.048; of four or more in all five boroughs, 0.060; of five or more in the Greater New York area, 0.074. Using the negative binomial model, these probabilities increase to 0.064, 0.079, and 0.102, respectively. There is some evidence that March 1975 was an unusually busy month for telephone building fires in Manhattan; however, there is less evidence that it was an unusually busy month for fires in the five boroughs or the Greater New York area. In other words, the influence of the February 27 fire upon building fire statistics during March decreases as ever-larger geographical areas are considered—a hardly surprising result.

IV. CONCLUSIONS

The Bell System has a very good record with respect to building fires. About 200 fires per year were reported between 1971 and 1977 in Bell System operating company buildings, or on roofs or grounds; of these, inside fires occurred at a rate of approximately 0.6 per million square feet per year. (However, unreported fires may increase this figure by 30 percent or more.) All fires but the New York fire on February 27, 1975 appear to be well modeled by a log-normal probability density function of damage with a median value of \$30 to \$80 (or a mean value of \$5,000 to \$13,000); about one percent of all fires exceeds \$100,000 in damage. The New York fire demonstrates that there is a small, but finite, chance of far more damaging fires; the best estimate of the probability of fires not following the log-normal damage distribution is 0.0002, based on 1960–1977 experience of 4496 fires. A tenth of all fires and half of all fire damage occurs in building unoccupied at the time of the fire. There is considerable evidence that fires occur in clusters; about 20 percent of all multiple-fire buildings had two or more fires that occurred near in time under similar circumstances. Furthermore, the enormous newspaper publicity of the New York fire may have been responsible for a modest but statistically significant increase in telephone building fires in the Greater New York area during the following month.

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