ESTIMATING FIRE LOSSES ASSOCIATED WITH FPE STAB-LOK® CIRCUIT BREAKER MALFUNCTION

Note: This version of the paper "Estimating Fire Losses Associated With Circuit Breaker Malfunction", published in IEEE Transactions on Industry Applications, Vol. 48, No.1, Jan/Feb 2012, p. 45, has been modified by the author to identify the brand name of the defective breakers, which was not identified in the body of the published version due to IEEE editorial rules.

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Abstract **-- A method is presented for connecting small branch circuit breaker functional test data to statistical fire loss data. Test results are presented for field samples of FPE Stab-Lok® circuit breakers, which have an abnormally high defect level. The test results and available electrical fire statistics are then used to estimate the annual number of fires and consequent injuries, deaths, and monetary loss associated with the defective breakers. An estimate is then made of the reduction of injury and loss that can be achieved by encouraging replacement of the FPE Stab-Lok® breakers. The role of the electrical safety community in promoting replacement of the defective breakers is discussed.**

Index Terms **-- Circuit Breakers, Circuit Breaker Testing, Fire, Overcurrent Protection, Fires, Electrical Fire Prevention.**

I. INTRODUCTION

Operational circuit breakers or fuses are required for fire safety in branch circuits due to the risk of overload and short circuit events that may occur from a variety of causes. If the protective device does not function properly when an overload or short circuit occurs, then the risk of fire is increased. Circuit breaker failure rates can be established by laboratory testing or by in-situ testing in buildings. The failure rate - and the nature of the failures - varies from brand to brand, being essentially zero for some brands and significant for others, as demonstrated in a published article describing a study of molded case circuit breakers tested by UL (Underwriters Laboratories, Inc.) [1].

In that study, two of the brands tested showed abnormally high failure rates. For the breakers identified in the article as brand "A", 8.6% of the 128 breakers tested failed to trip at 135% of rated current, the standard "must trip" test value. For brand "D", two out of the six breakers that were tested failed to trip at 135% of rated current, and one of those two failed to trip when tested at 200% of rated current. The data of that article demonstrate a substantial brand-to-brand variation in failure rate and severity of failure. The article does not discuss the safety implications of the failure of the brand A and brand D breakers to trip properly.

Until now, there has been no way to estimate fire losses due to circuit breaker malfunctions such as reported in that study. The inability to "connect the dots" between circuit breaker malfunction and fire/injury incidents stems mainly from the fact that fire investigation is focused on identifying where the fire started ("origin") and the source of ignition ("cause"). In the authors' experience, conventional fire investigations seldom go to the depth required to firmly establish whether a circuit breaker did or did not function properly at the time of the fire. For a specific fire incident, the investigator may suspect that circuit breaker malfunction at the time of fire ignition was a contributing factor, but proving it is extremely difficult.

On a larger scale, however, by the method presented in this paper, it is possible to estimate the contribution of a line of defective circuit breakers to annual fire losses. This is an important tool for fire prevention. It is the authors' experience that there is substantial resistance to replacing breakers, or recommending replacement, without demonstration of both defect and fire risk. Demonstration of defective performance alone is not sufficient.

The method presented in this paper allows an estimate to be made of the number of electrical fires associated with faulty performance in a line of known defective circuit breakers. The fire loss reduction that would result from accelerated replacement of the defective breakers is then also estimated.

II. METHOD OF ANALYSIS

A. Definition of Fire

For the purpose of this analysis, a "fire" is an event that is included as such in the specific set of fire statistics being employed. The subject population of the set might be industrial, office, commercial, hospital, residential, or all such structures combined. For instance, in the example provided later in the paper, the subject population is residential structures, and a "fire" in the data set is an event reported as a fire that required an emergency services response to a residence.

B. Scope

The method has been developed to address a specific line of small branch circuit breakers installed in a large number of residential, office, commercial, industrial, hospital, and other types of buildings. Groups of these breakers are installed in service entrance panels or sub-panels to feed 15A and 20A convenience circuits as well as dedicated lighting and equipment circuits to about 70A rating. The application example provided in this paper is for residential installations, for the sole reason that the residential statistical fire data is publicly available.

C. Precision of Resulting Estimates

Calculated results are not rounded off. This is done so that the calculations can be easily followed and checked by those who wish to refine the method or test the effect of alternate assumptions. The lack of rounding is not meant to imply a level of precision. The calculated number of fires and related injuries, deaths, and monetary loss are considered to be estimates of the correct magnitude.

D. Method

The fundamental role of a circuit breaker or fuse is to interrupt an abnormal electrical event that involves excess current. Some abnormal electrical events produce a "competent source of ignition" in the particular setting, meaning that a fire will occur unless the current is interrupted in time. A portion of these electrical ignition events involve excess current, while others do not. Those that involve excess current at a level that would activate a circuit breaker or fuse in time to prevent fire ignition are "***Interruptible***", while those that involve current too low to activate the over-current protection device are "***Non-interruptible***".

From an electrical fire ignition standpoint, the basic concepts are:

- An ***Interruptible*** electrical ignition event causes a fire only if the circuit protection device is defective, improperly sized, miswired, or has been tampered with.
- A ***Non-interruptible*** event causes a fire whether or not the associated fuse or circuit breaker is properly sized and operative. (Some non-interruptible fire causing events might be interrupted by newly developed devices, such as arc-fault interrupters.)
- ***The total number of actual electrical fires*** consists of those ignited by electrical ignition events that are ***Non-interruptible*** plus a portion of ***Interruptible*** events which become fires due to improper operation of the circuit protective device. The improper operation may be due to a defect, improper rating or type, miswiring, or tampering.

Fig. 1 illustrates these concepts. The red (dark) and cross-hatched areas represent the total number of electrical fires in a year, consisting of those that are non-interruptible plus those that could be interrupted but are not due to lack of proper circuit protection. The total number of electrical fires in a year is generally known or derivable from annual fire causation statistics.

The risk of an electrical ignition event occurring, interruptible or not, is considered to be independent of the type of circuit protection device (fuse or circuit breaker) and also independent of the brand of circuit protection device. For fused circuits, the risk of malfunction -- failure to open on excess current -- is essentially zero. In contrast, the risk of malfunction of a circuit breaker depends on the brand and/or type, as noted in the publication previously discussed [1]. The specific concern centers on a brand and type of circuit breakers, no longer manufactured, that has been proven to have a uniquely high failure rate. These are labeled "Brand X" in Fig. 1. The annual number of electrical fires associated with defective operation of the Brand X breakers is represented by the area of the top section of the Brand X portion of fires in Fig. 1.

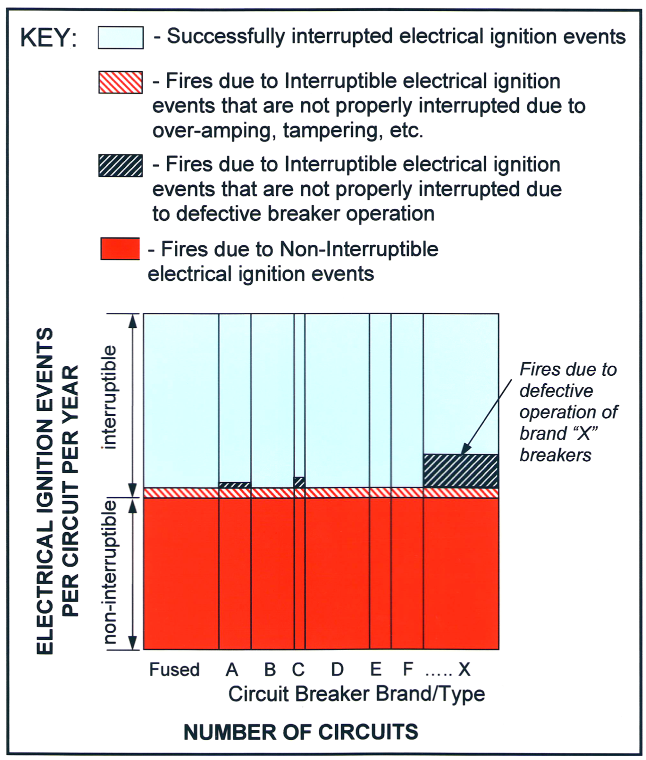

Fig. 1. Electrical fires and circuit protection functionality

The total number of electrical fires is the sum of the red (dark) and cross-hatched areas in Fig. 1, which is described by the following equation.

$$\mathbf{F_E = NY+ND_0Z+N_AD_AS_AZ+N_BD_BS_BZ+ ...+N_XD_XS_XZ} \quad \mathbf{(1)}$$

Where:

$\mathbf{F_E}$ = Total number of residential electrical fires per year

N = total number of circuits

N_A, N_B, . . . N_X = total number of circuits equipped with Brand A, Brand B, ...Brand X circuit breakers respectively, in that year.

Y = Rate of occurrence of non-interruptible electrical Ignition events, per year per circuit

Z = Rate of occurrence of interruptible electrical ignition events, per year per circuit

D_0 = factor accounting for low-probability random defects, over-amping, tampering, & etc.

D_A, D_B, . . . D_X = fraction defective (above D_0) for Brand A, Brand B, ...Brand X

S_A, S_B, . . . S_X = **"Defect Severity Factor"** for Brand A, Brand B, Brand C, ….Brand X. This is a factor by which to adjust the circuit breaker failure rate (failure to meet standard requirements) downward, as appropriate, so that the specific nature of the test failures are considered in calculating the probability of fire ignition. If the defects of Brand X circuit breakers cause them to be jammed (non-functional), then S_X would be 1.0, but if the performance defect is a small offset in calibration, then S_X would be of the order of 0.1.

The terms $N_A D_A S_A Z + N_B D_B S_B Z + \ldots + N_X D_X S_X Z$ are the fires attributable to the excessive defect level of circuit breakers Brand A, Brand B ......Brand X respectively, so that:

$$F_X = N_X D_X S_X Z \qquad (2)$$

= fires due to defective operation of Brand X breakers.

There is one brand of circuit breakers known to have a uniquely high failure rate. Equation (1), which is a general case, can be simplified by considering that the population of circuit protection devices consists of two groups, one being FPE Stab-Lok®, the brand that has an abnormally high failure rate, and the second being all others combined. The simplified equation for the total number of electrical fires in the year is then:

$$F_E = N\,Y + N\,D_0\,Z + N_{FPE}\,D_{FPE}\,S_{FPE}\,Z \qquad (3)$$

For the practical application of the method, it is useful to define as a parameter the ratio of interruptible to non-interruptible fire ignition events as follows:

$$R = Z / Y \qquad (4)$$

The ratio R may be reasonably estimated, even though numerical values or estimates for its components are lacking. To illustrate, consider a hypothetical experiment to quantify R, in which the overcurrent protective devices (fuses and/or circuit breakers) in the service entrance panels of all the buildings in a large region of the country were disabled (or bypassed). The rate of occurrence of electrical fires in that region would then increase, since all interruptible fire ignition events would then become actual fires. If the rate of electrical fires doubled, that would reflect the ratio R=1; if it tripled, then R=2; and so on.

Substituting R for Z/Y in (3), solving for Z, and using that result in (2), the result is an expression for F_{FPE}, the number of electrical fires associated with defective performance of FPE Stab-Lok® circuit breakers:

$$F_{FPE} = N_{FPE}D_{FPE}S_{FPE}F_E/(N/R+ND_0+N_{FPE}D_{FPE}S_{FPE}) \qquad (5)$$

III. Application

A. Performance of FPE Stab-Lok® Circuit Breakers

In the early 1980s, the U.S. Consumer Product Safety Commission (CPSC) tested federal Pacific Electric (FPE) Stab-Lok® circuit breakers and found that they did not reliably trip as specified by applicable codes and standards. Under certain conditions some would jam completely. Table 1 is a summary of the test data developed by the CPSC at that time.

TABLE I
Summary of CPSC Test Results for FPE Stab-Lok® Circuit Breakers

Type of FPE Stab-Lok® Breakers Tested	Number Tested	No-Trip Failures @135% of Rated Current*	Critical Safety Failures**
CPSC [2]			
Single-Pole	14	4 (28%)	1 (7%)
Double-Pole	27	20 (74%)	5 (19%)
Wright-Malta (for CPSC) [3]			
Double Pole (full width)	122	62 (51%)	12 (10%) ***

* UL Standard 489 test requirement [4]. Breaker must trip within 1 hr at 135% of rated current. The Numbers in this column include the samples that are also listed as critical safety failures.

** CPSC definition: failed to trip @200% of rated current, or jammed [2].

*** After application of abbreviated version of UL 489 mechanical life test, 1% failure before life test.

More recently, performance data has been developed to determine the performance of the FPE Stab-Lok® circuit breakers as they presently exist in buildings, many years after initial installation. More than 564 FPE Stab-Lok® breakers were tested from 35 homes across the United States, and 830 FPE Stab-Lok® breakers were tested from a single high-rise apartment building. The breakers were in complete sets in panels that had been removed for reasons of service upgrade, home improvement, and/or safety concerns. The breakers were tested as received, with no additional conditioning, so as to reflect their actual operational capability in service. Breakers received with the toggle in the "off" position were toggled "on" and left in that position until tested. Breakers with visible damage, such as a cracked case, were not tested.

A test procedure is utilized that encompasses the UL489 135% test criterion, which is that breakers of this type must trip within 1 hour at 135% of rated current. A computer-based data acquisition and control system starts application of current at 100% of the breaker's current rating, and then, over a period of one hour, increases the current linearly until 135% of rated current is reached. If the breaker has not yet tripped (opened the circuit – current drops to zero) by that time, the current is held constant at 135% for one hour. If the breaker has not tripped by the end of one hour at 135% of rated current, then the ramped increase resumes. This method provides data as to the actual calibration (minimum tripping current) for the breaker. The data acquisition and control system records and plots current vs. time for each breaker tested. Note that double pole breakers are tested one pole at a time.

Representative test results for FPE Stab-Lok® breakers that pass and fail the standard requirements are shown in Fig.2 through Fig.5.

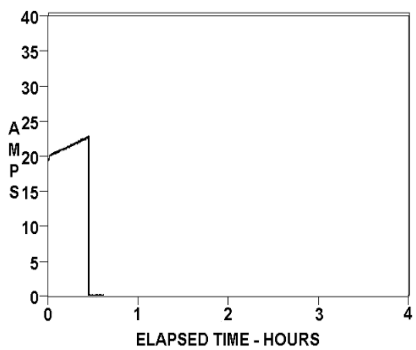

Fig. 2.Correct operation, 20A FPE Stab-Lok® breaker

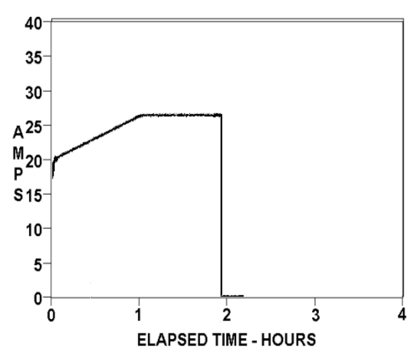

Fig. 3. Marginal operation, 20A FPE Stab-Lok® breaker

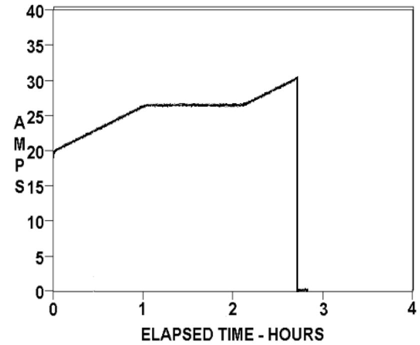

Fig. 4. Calibration Failure, 20A FPE Stab-Lok® breaker, fails to trip as required at 135% of rated current within one hour, trips at 31A (155% of rated current.

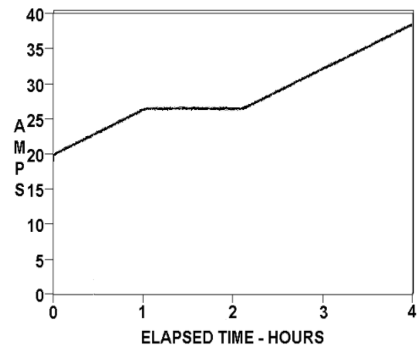

Fig. 5. Jammed 20A FPE Stab-Lok® breaker. Does not trip when tested to current over 200% of rating. (Mechanical jamming confirmed by X-Ray imaging.)

Two types of failure behavior are illustrated above. Calibration failures, such as shown in Fig. 4, vary in severity, with trip point current ranging from just over the allowable 135% limit to more than 150% of rating. The hazard posed by this type of failure is similar to that of "over-fusing" (or "over-amping") -- using fuses or breakers with a higher current rating than appropriate for the circuit application.

For the breakers that have been tested, those that sustain current above 150% of their rating are most often found to be jammed. The jammed breakers do not trip at any applied current condition. Typically, the breaker's latching device has released, but its mechanism does not actuate to open the electrical contacts no matter what current is applied. This constitutes a major compromise of electrical safety, equivalent to bypassing a breaker or fuse (the "penny behind the fuse"). Jamming is confirmed by radiographic ("X-Ray") imaging. Fig. 6 and Fig. 7 show X-Ray images of FPE Stab-Lok® two-pole breakers, one jammed and the other properly tripped. The images are of the mechanisms of the two poles superimposed.

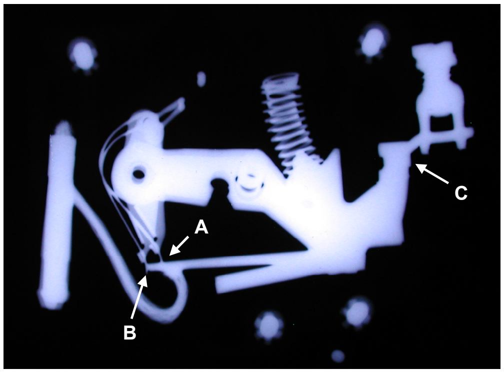

Fig. 6. Jammed FPE Stab-Lok® 2-pole breaker. Arrow A points to the tip of the trip lever of the overloaded pole, which disengaged from the end of its bimetallic strip, B. The mechanism is jammed, however, and both sets of contacts, C, remain closed.

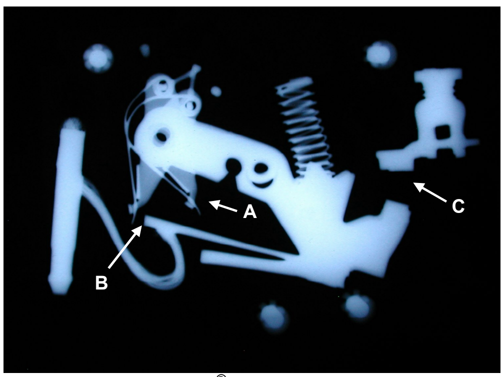

Fig. 7. Tripped FPE Stab-Lok® 2-pole breaker. The trip lever of the overloaded pole ("A") disengaged from its bimetal strip ("B"). The mechanism operated properly and opened both sets of contacts ("C").

Tables 2 and 3 show the results of recent performance testing for two populations of FPE Stab-Lok® circuit breakers, the first being a set of 830 breakers from a single structure and the second consisting of a more random sample (in terms of breaker manufacturing lots, time since installation, & etc.) of 564 breakers from 35 homes across the country.

TABLE 2
SUMMARY OF TEST RESULTS FOR 830 FPE STAB-LOK® CIRCUIT BREAKERS FROM A 63-UNIT APARTMENT BUILDING

Type of FPE Stab-Lok® Circuit Breakers Tested	No. Tested	No Trip Failures @135% of Rated Current*	Critical Safety Failures**
Single-Pole 15A	241	47 (20%)	0
Single-Pole 20A	211	17 (8%)	0
Double-Pole 20A	194	67 (35%)	10 (5%)
Double Pole 30A	77	32 (42%)	6 (8%)
Double Pole 40 Amp & higher	107	75 (70%)	8 (7%)

* Includes samples that are also critical safety failures
** Failed to trip @200% of rated current, or jammed.

TABLE 3
SUMMARY OF TEST RESULTS FOR 830 FPE STAB-LOK® CIRCUIT BREAKERS FROM 35 HOMES ACROSS THE UNITED STATES

Type of FPE Stab-Lok® Circuit Breakers Tested	No. Tested	No Trip Failures @135% of Rated Current*	Critical Safety Failures**
Single-Pole	425	71 (17%)	4 (1%)
Single Pole GFI/Breaker	5	3 (60%)	4 (80%)***
Double Pole	134	46 (34%)	14 (10%)

* Includes samples that are also critical safety failures
** Failed to trip @200% of rated current, or jammed.
*** Includes GFI function failure on breaker that passed overcurrent test.

The overall defective performance rate for the 830 FPE Stab-Lok® breakers of Table 2 is 28%, and for the 564 FPE Stab-Lok® breakers of Table 3 the defective performance rate is 21%.

B. *Estimating the Annual Number of Fires Associated With the Defective Breakers*

The test data of Table 3, being closest to a random sample of the installed FPE Stab-Lok® breakers, is used to estimate the number of fires that occur due to failure of these breakers to operate properly. These are fires that would not occur if the breakers tripped correctly. (The breakers themselves are not the ignition source.) Residential data are used for these estimates, as they are publicly available and residential installations represent the major application for the FPE Stab-Lok® breakers. Estimates for other types of buildings should be proportional to the usage of these same breakers, assuming that the risk of an electrical fire ignition event is about the same. We employ (5), derived previously, and values for the various terms that follow to calculate the result.

$$F_{FPE} = N_{FPE} D_{FPE} S_{FPE} F_E / (N/R + N D_0 + N_{FPE} D_{FPE} S_{FPE}) \quad (5)$$

Values for the terms in (5), are chosen as follows:

N_{FPE} = 270x10^6 Estimated number of FPE Stab-Lok® circuit breakers in residential installations. Approx. 300 million originally less 10% allowance for attrition.)

N = 1,900x10^6 Estimated total number of circuits in residential housing in the USA, based on Census Bureau housing data for the median year for the years for which the CPSC fire and injury data (below) applies, and an average of 16 circuits per housing unit.

F_E = 104,520 Average number of residential electrical fires per year reported by the CPSC for 1999 through 2003 [5].

D_0 = 0.01 Allowance for "normal" level of defective, over-amped, and tampered circuit protective devices in residential installations.

D_{FPE} = 0.20 The defect rate for FPE Stab-Lok® breakers is based on the test results reported above in Table 3 (564 tested, 120 defective), less **D_0**.

S_{FPE} = 0.5 The value for S is a approximate weighted average based on 0.2 for the range of calibration failures seen in the sample testing and 1.0 for jamming failures.

R = 2 This is an assumed value for **R,** considered to be of the correct magnitude (ie: That risk of an electrical fire triples if the over-current protection is bypassed. See explanation and discussion regarding hypothetical experiment at earlier definition of **R**.)

Employing these values in (5) yields the following result for the number of residential electrical fires attributable to the failure of FPE Stab-Lok® breakers to trip properly:

F_{FPE} = 2,829 ***residential electrical fires per year attributable to defective operation of FPE Stab-Lok® circuit breakers.*** These are interruptible electrical ignition events that result in fire due to circuit breaker malfunction.

C. Estimating Residential Fire Losses Due to Defective FPE Stab-Lok® Circuit Breakers

The CPSC compiled data for deaths, injuries and monetary loss associated with residential electrical fires in the United States for the years 1999 through 2003 [5]. The average values for those five years are:

104,520 residential electrical fires per year

4,284 injuries per year due to residential electrical fires

496 fatalities per year due to residential electrical fires

$1.5 billion per year residential property loss due to residential electrical fires

Allocating the annual injuries, deaths, and property losses proportionally to the estimated 2,829 fires attributable to the defective FPE Stab-Lok® breakers, then the losses due to their continuing presence in homes across the country are calculated to be:

116 injuries per year
13 deaths per year
$40.4 million per year property loss

D. Estimating Reduction of Fire Loss Achievable by Promoting the Replacement of FPE Stab-Lok® Breakers

It is the authors' experience that the FPE Stab-Lok® breaker defect problem most often comes to the forefront at the time of sale of a building. At present, many pre-sale inspection reports cite the FPE Stab-Lok® breakers as a latent safety exposure and recommend that they be replaced. Their recommendations are often negated by electricians', realtors', and electrical inspectors' statements based on erroneous interpretations of the CPSC's 1983 press release [6], or on arguments that the breakers are (UL) "listed and labeled" and therefore meet code requirements.

If authoritative safety organizations issue a warning about the increased fire risk associated with the defective breakers, and a recommendation that they be replaced, it is expected that the rate of replacement at the time of property sales would increase. The resulting safety benefit can be estimated.

As previously derived, the number of fires due to FPE Stab-Lok® breaker malfunction is:

$$\mathbf{F_{FPE} = N_{FPE}\, D_{FPE}\, S_{FPE}\, Z} \qquad \textbf{(2)}$$

D_{FPE} and **S_{FPE}** are properties of the population of FPE Stab-Lok® breakers, and may be considered as essentially constant. The rate of occurrence of interruptible electrical ignition events, **Z**, is not a property of the breakers, and it may also be considered as essentially a constant. The number of fires due to the defective breakers, **F_{FPE}**, is then directly proportional to **N_{FPE}**, the number of circuits equipped with these breakers.

For a given replacement rate, we can determine the number of FPE Stab-Lok® breakers remaining each year, and the associated reduction of fires and losses. The present rate of replacement is assumed to be of the order of 0.01 (1% per year). With the issuance of an effective warning as to the increased fire risk associated with the defective FPE Stab-Lok® breakers, it is the opinion of the authors that the annual replacement rate is likely to increase to about 0.05 (5%), which is the approximate rate of building sales. A spreadsheet analysis is used to calculate the number of FPE Stab-Lok® breakers remaining, by year, for each replacement rate. The annual fire, injury, and loss figures are then calculated, being proportional to the number of FPE Stab-Lok® breakers remaining. The difference between the two cases is then determined. Table 4 shows results for the first ten years.

The cumulative benefit over the ten year period is determined by adding the numbers in each column of Table 4, resulting in the following estimates:

Reduction of Fires = 5,212
Reduction of Injuries = 214
Reduction of Deaths = 25
Reduction of Property Loss = $74.4 million

TABLE 4
POTENTIAL FIRE LOSS REDUCTION RESULTING FROM ENCOURAGING REPLACEMENT OF FPE STAB-LOK® CIRCUIT BREAKERS (BASED ON AN INCREASED RATE OF REPLACEMENT FROM 1% PER YEAR TO 5% PER YEAR)

	REDUCTION OF			
YEAR	**FIRES**	**INJURY**	**DEATHS**	**PROPERTY LOSS ($MILLIONS)**
1	113	5	1	1.6
2	220	9	1	3.1
3	320	13	2	4.6
4	413	17	2	5.9
5	501	21	2	7.2
6	584	24	3	8.3
7	661	27	3	9.4
8	734	30	3	10.5
9	801	33	4	11.4
10	865	35	4	12.3

IV. DISCUSSION

FPE Stab-Lok® breakers have an unacceptably high rate of defective performance. They are presently installed in about 17 million homes across the country as well as in countless additional buildings of other types. The estimated 2,829 residential electrical fires per year nation-wide associated with the defective breakers amounts to about one fire per year for every 6,000 FPE Stab-Lok® equipped homes. It constitutes about 2.5% of the annually reported residential electrical fires in the United States.

The performance test data used to derive the fire loss estimates for the FPE Stab-Lok® breakers are consistent with previous lab and field test results on those breakers by several entities, as, for example, those of the CPSC (Table I). The defective performance has now been demonstrated and quantified to a much higher degree of statistical certainty.

Incredibly, although factual information and test data as to the defective performance of FPE Stab-Lok® breakers has been available for at least a quarter of a century to those who would seek it out, there is no nationally respected electrical safety organization or authority that has taken the initiative to suggest publicly and in plain language that they be changed in the interest of fire safety

Because of its previous investigation of these breakers, the CPSC is considered by many to be the public authority on this matter. The CPSC has been essentially dormant on this issue since 1983, however, except for a recent clarification of its 1983 press release. A note has been added explaining that the press release announces that (in 1983), " ... the *"Commission closed the matter without making a determination as to the safety of the ... circuit breakers or the accuracy of the manufacturer's position on the matter."* The added note makes it less likely that the 1983 press release could be misinterpreted. It should now be clear that there is no validity to any statement that the CPSC found the FPE Stab-Lok® breakers to be safe. This recent action by the CPSC falls short of recommending that the defective breakers be replaced, however.

A considerable amount of new information has come to light since the CPSC closed its investigation in 1983. It has now been clearly demonstrated that defects exist across the entire FPE Stab-Lok® circuit breaker line; they are not limited to the full-size two-pole breakers that the CPSC included in its formal investigation [3], [6]. The test results also show that jamming of the FPE Stab-Lok® 2-pole breakers occurs at a relatively high rate in breakers that were installed in homes. That clearly answers the question as to whether the accelerated endurance test applied by the CPSC, which caused about 10% of the two-pole breakers to jam, correctly predicted the field performance with regard to jamming [3], [6]. It did.

Additionally, in 2002 in a class action lawsuit in New Jersey, the Judge ruled that the manufacturer of the FPE Stab-Lok® breakers had committed fraud under the New Jersey Consumer Protection Act by, over a period of many years, applying the (UL) labels to product that did not meet the required performance standards [7]. The Judge's decision was based primarily on the company's own documents. Public documentation has also come to light showing that virtually all circuit breakers in the FPE Stab-Lok® line lost their (UL) listings when the company's deceptive testing practices were uncovered [8], [9]. That, in combination with the demonstrated high defect rate, negates claims that FPE Stab-Lok® breakers are "suitable for the purpose" because they appear to be UL "listed and labeled" [10]. Until about 1979, UL was apparently unaware of the company's deceptive practices. When they became aware, the company lost most of its circuit breaker listings, since their breakers could not reliably pass the UL tests, and the company eventually ceased manufacturing operations. The trade and public were never warned, however.

IV. CONCLUSION

An important measure of our electrical safety system's performance is how it behaves when things go wrong. In that regard, in this instance of fraudulent testing and proven defective circuit breakers, our electrical safety system has, so far, failed badly. There is no guidance from any of the nationally-recognized electrical safety organizations that the FPE Stab-Lok® breakers should be replaced due to the high defect level and the resulting increased risk of fire and injury.

Presently, an estimated 54 million defective FPE Stab-Lok® circuit breakers exist among about 270 million that are still installed in homes across the United States. By the method presented in this paper, it is estimated that they are a causative factor in nearly 3,000 residential fires annually, resulting in about 14 fatalities, 116 injuries, and $40 million in property damage each year.

The estimates of fires, losses, and loss reduction that have been developed and presented in this paper are certainly subject to adjustment based on refined data, assumptions and/or methodology. The following conclusion is accurate, however; there are substantial fire losses due to the defective operation of the FPE Stab-Lok® circuit breakers.

Until now, an inability to quantify the safety consequences of the FPE Stab-Lok® circuit breaker defects has made it difficult to motivate safety organizations to take action on this issue. This paper has provided the data, method of analysis, and results to eliminate that obstacle. Considering the estimated magnitude of the related fire losses, it is reasonable to expect organizations concerned with fire safety to take action to encourage the replacement of the FPE Stab-Lok® circuit breakers.

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