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THE FEASIBILITY OF QUANTITATIVELY ANALYZING INVESTMENTS IN LOSS PREVENTION ACTIVITIES

Lawrence M. Krasner, et al

Factory Mutual Research Corporation

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FINAL TECHNICAL REPORT

THE FEASIBILITY OF QUANTITATIVELY ANALYZING INVESTMENTS IN LOSS PREVENTION ACTIVITIES PHASE II

By
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L. M. Krasner and S. A. Wiener

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13 ABSTRACT

The purpose of this effort was to refine and simplify for application a fire risk management system developed during the feasibility study phase of this contract and described in the Final Technical Report, Contract No. N00025-70-C-0011 dated July 1971. The intent was to provide a more realistic second generation model which would be simple to apply and more closely suited to the needs of the Naval Shore Establishment. This report describes the new model, the rationale used in its development and the field testing conducted to evaluate its applicability directly to Navy problems.

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The Feasibility of Quantitatively Analyzing Investments in Loss Prevention Activities Phase II

By: L. M. Krasner and S. A. Wiener

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Approved by:

J. B. Smith
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FOREWORD

In developing a risk management methodology under Phase II of this study program, the enthusiastic support and cooperation of Messrs. H. Anderson, NavFac; R. Darwin, NavMat; and C. Burtner, NavShips are gratefully acknowledged. In addition, special thanks are due Mr. R. Sheridan, Western Division, NavFac and all of his personnel for their cooperation and assistance.

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ABSTRACT

The purpose of this effort was to refine and simplify for application a fire risk management system developed during the feasibility study phase of this contract and described in the Final Technical Report, Contract No. N00025-70-C-0011, dated July 1971. The intent was to provide a more realistic second generation model which would be simple to apply and more closely suited to the needs of the Naval Shore Establishment. This report describes the new model, the rationale used in its development and the field testing conducted to evaluate its applicability directly to Navy problems.

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INTRODUCTION

In 1970, a study was initiated by the Naval Facilities Engineering Command (NavFac) to determine the feasibility of designing a fire risk management system. It was recognized that NavFac's method of operation, with respect to fire protection engineering surveys and resulting recommendations, was in need of improvement. A systematic analysis of fire protection investment alternatives was needed to objectively assess the fire risk.

Clearly, funding would never be available to implement all fire protection recommendations regardless of the soundness of the engineering judgment generating the recommendations. Initiating a recommendation for every fire protection deficiency resulted in several undesirable features:

1) Too much paper work was generated;
2) An ever increasing backlog of fire protection deficiencies was created;
3) Since no systematic method for comparing the relative benefit of fire protection investment alternatives existed, inconsistencies in analysis occurred. More important deficiencies could thereby be lost in the shuffle while alternatives providing less significant risk reduction would receive attention;
4) Fire protection engineer's recommendations are often regarded with less than full credibility due to their large number and lack of funds to implement them.

The development of a risk management methodology designed for field division level application in connection with fire protection surveys and reports proved feasible. FMRC was successful in formulating a first generation model of such a methodology[(1)] which included consideration of strategic importance, life and dollar risk, fire frequency/severity and recommendation cost.

Based upon the success of that effort, the contract was extended into a second phase, primarily in order to refine the system and simplify its application. This report describes the resultant second generation methodology.

[(1)] The Feasibility of Quantitatively Analyzing Investments in Loss Prevention Activities, Miller, M.J., Krasner, L.M., Wiener, S.A., July 1971.

The system now more realistically provides objective justification for recommendations while allowing for the screening out of less important deficiencies. Of equal significance, consistency of application demanded by the system results in consistency of analysis among individuals. In addition, it can provide meaningful guidance to commanding officers and major claimants for assessing the importance of fire protection recommendations relative to each other.

II

FIRE RISK MANAGEMENT METHODOLOGY

2.1 DEFICIENCIES OF FIRST GENERATION METHODOLOGY

The first generation methodology, although usable, failed to treat realistically certain significant aspects of the overall risk management problem. It combined several difficult-to-isolate parameters, circumvented hard-to-resolve issues and incorporated difficult-to-obtain data items which tended to encumber the use of the system. Since the intent of the methodology is to provide a simple, straight forward and realistic technique for assessing relative merit, it was felt that in order to achieve maximum understanding and acceptance, the deficiencies should be corrected wherever possible. For purposes of background, continuity and comparison the first generation major deficiencies are listed:

1) Fire severity was incorporated with fire frequency into a combined general measure which related to dollar and life loss equally instead of being individually associated with each independent variable;
2) No measure of protection improvement was possible; thus, the oversimplified assumption that all fire protection projects would result in equal risk reduction was made;
3) No means of handling special problems related to pier ship protection and activity-wide improvements (e.g., water supply and piping changes) was provided;
4) Rating of strategic importance required high level personnel to assign values to several critical parameters resulting in a difficult, if not impossible, determination of nearly absolute figures in a system designed around relativity;
5) Occupancy types for determination of fire frequencies were categorized for industrial rather than Navy environments.

As will be seen these deficiencies are corrected in the second generation methodology.

2.2 SECOND GENERATION METHODOLOGY

2.2.1 General Overview

The second generation methodology incorporates into a relative ranking system, the same variables as its predecessor; strategic importance; life risk; dollar risk; fire frequency; fire severity; and recommendation cost. The treatment of these variables is, however, more realistic and meaningful than before.

While correcting the deficiencies discussed previously, several important changes were generated. The rating system now revolves around a before-and-after concept. For a given protection deficiency, it is necessary first to evaluate the probable loss with conditions as given. This is done by starting with potential loss and then using severity measures specific to the environment to modify to a probable loss level. The probable loss is then recalculated assuming the recommendation improving the deficiency is implemented. It is, therefore, possible in this before-and-after manner to calculate the reduction in risk or the expected improvement. With this capability one can compare various solutions to a specific problem as well as different problems. Stemming from the development of this concept was the realization that the ultimate ranking of each potential recommendation should include consideration of two factors, each of which incorporates the same basic variables: 1) Intrinsic worth of the structure under consideration for fire protection improvements; and 2) the probable level of improvement (risk reduction) resulting from a specific recommendation.

The general system operation involves the following steps discussed in detail in Sections 2.2.2-2.2.4:

1) Determine intrinsic values of the variables;
2) Rate the variables "before";
3) Rate the variables "after" and determine the differences;
4) Subject modified values of the variables to a cut-off rule which determines whether further consideration should be given to the recommendation;
5) If further consideration is warranted, substitute those values into a ranking formula which incorporates fire frequency and recommendation cost considerations. A point rating is thereby generated allowing relative comparison with other fire protection recommendations.

2.2.2 Rating and Point Value Assessments

2.2.2.1 Strategic Importance - The strategic importance can be treated in a very detailed and complex manner but the results and benefits of such an exercise would be doubtful. The effort required in the field for such treatment would be extensive and even then some of the data could prove unattainable because of security. In order to provide a usable assessment of strategic importance which can be easily and quickly compiled, the facilities or supplies are rated in two general areas: 1) by the type of facility or supplies with respect to strategic role performed; and 2) by the relative effect of total loss upon Navy mission capability (calculated in two steps). The sum of the rating numbers in the two areas gives a rating value for the strategic importance, S.

Table VII (Section 2.2.3) is then used to convert that rating into a point value. The following procedure is employed to calculate the rating for S.

1. Classify the type of facility or supplies with respect to its strategic role. Rate from 0-4 according to Table I.

TABLE I STRATEGIC ROLE

	Weapons or Communications System Involved		
Support	None	Minor	Major
None	0	0	0
Indirect	0	1	2
Direct	0	3	4

2. Estimate the importance of the facilities or supplies to Navy mission capability. Rate from 0-6 according to the following two-part procedure.
   a. Determine the effect of loss of facilities or supplies on the activity's mission capability. Place X in the appropriate block of Table II.

TABLE II ACTIVITY MISSION EFFECT

	Duration of Effect		
Degree of Strain	Brief	Moderate	Extended
Slight	Block A	Block B	Block C
Significant	Block D	Block E	Block F
Severe	Block G	Block H	Block I

Definitions:

t = time

Brief:	$t \leq 1$ week
Moderate:	1 week $< t \leq 6$ months
Extended:	$t > 6$ months
Slight:	Little or no degradation of mission capability or small increase in effort required to maintain capability.
Significant:	Noticeable degradation of mission capability despite increase in effort, or extreme effort required to maintain capability.
Severe:	Serious degradation of mission capability, and inability to recover full capability despite extreme effort.

b. Estimate the effect of such loss on the Navy mission capability. From the following four classifications, select the appropriate conditions and read out the rating number occupying the block X'd in Part a.

1) There are many facilities or supplies of the same type readily available; and both of the following apply:

   a) The Navy can compensate for the loss easily.

   b) A second loss of similar magnitude would not be serious.

Block A 0	Block B 0	Block C 0
Block D 0	Block E 0	Block F 1
Block G 0	Block H 1	Block I 2

2) There are few facilities or supplies of the same type readily available; <u>and at least one of the following applies</u>:

a) The Navy can compensate for the loss but with some difficulty.

b) A second loss of similar magnitude would be serious.

Block A 0	Block B 1	Block C 2
Block D 1	Block E 2	Block F 3
Block G 3	Block H 4	Block I 5

3) There are very few facilities or supplies of the same type readily available; <u>and at least one of the following applies</u>:

a) The Navy can compensate for the loss but with great difficulty.

b) A second loss of similar magnitude would be critical.

Block A 2	Block B 3	Block C 4
Block D 3	Block E 4	Block F 5
Block G 4	Block H 5	Block I 6

4) The initial loss would be critical.

Block A *	Block B *	Block C *
Block D *	Block E *	Block F *
Block G 5	Block H 6	Block I 6

*It is unlikely that a classification 4 is consistent with these blocks. Question further to determine explanation and reduce to classification 3 or assign to block G, H, or I of Classification 4.

3. Sum the ratings from 1. and 2. to obtain a total strategic rating S.

2.2.2.2 Human Life Risk - Measuring the risk to human life associated with a fire area involves consideration of the following factors: the number of people in the area; the condition of the people; and the condition of the fire area itself in terms of fire protection and personnel fire safety. As indicated in section 2.2.1, the variable, life risk, is separated into two elements; intrinsic life risk and probable reduction of life risk. By considering intrinsic life risk independently, the methodology thereby provides some credit to a potential recommendation simply because the potential for life loss exists.

Intrinsic life risk, L_1, is the maximum number of people exposed within the potential fire area under consideration. Potential fire area is determined by considering passive protection (i.e. horizontal and vertical fire stops) but disregarding active protection (sprinklers, etc.). Table VIII (Section 2.2.3) is then used to determine the point value associated with the intrinsic life risk.

To define a measure of probable reduction of life risk, probable life risk, L_1, is measured twice: once, as the facility exists; and again as it would measure if the fire protection recommendation were accomplished. Probable life risk is determined by starting with the intrinsic life risk. Then, according to the condition of the occupants and the fire area, that number is modified by using percentages designed to reflect the relative severity of different sets of circumstances. The resulting number yields the relative measure designated as probable life risk. The calculation of probable life risk before and after indicates the expected change in life risk. This change is then translated into a point value according to Figure 1 (Section 2.2.3). The following seven-step procedure is employed to calculate the change in life risk, ΔL.

1. Determine intrinsic life risk, L_1, the total number of personnel associated with the potential fire area at any one time, during normal operations.

2. Determine a general classification from among the following, based on the condition of the occupants.

   a. Mobile and awake.

   b. Intermediate: Mobile and awake, but lower probability of escape (child day care centers, overcrowded areas, etc.).

   c. Personnel likely to be asleep or physically unable to move from the fire area. (Barracks, Brigs, Hospitals, Nurseries, etc.)

3. Determine a classification for protection from among the following:

   a. Adequate protection and meeting personnel fire safety standards, or with minor departures only.

   b. Inadequate or no protection but meeting personnel fire safety standards, with minor departures only.

   c. Adequate protection but personnel fire safety standards not met--potentially dangerous departures from standards exist.

   d. Inadequate or no protection and potentially dangerous departures from personnel fire safety standards exist.

4. Determine a percentage from Table III, based upon the classifications from steps 2 and 3.

TABLE III LIFE RISK MULTIPLIERS(%)

Protection/Personnel Safety Classification	Occupants Condition Classification: a	b	c
a	1	5	10
b	2	8	20
c	5	12	30
d	9	20	50

5. Multiply L_1 by the percentage selected from Table III. Round to the nearest whole number to obtain L.

6. Assume the recommendation were implemented. Then, repeat steps 1. through 5. to determine L, After.

7. Determine the difference between L Before and L After from steps 5. and 6. respectively to obtain ΔL.

Note: ΔL results from changes effecting steps 1. and/or 3., depending on the nature of the recommendation.

2.2.2.3 Dollar Risk - The procedure for measuring intrinsic dollar risk and probable dollar risk reduction is similar to that used in Section 2.2.2.2 to measure human life risk. Intrinsic dollar risk, D_1, is the maximum potential dollar loss associated with the potential fire area. It is represented by building and contents replacement cost, including conflagration potential. Table IX (Section 2.2.3) is then used to assign points to D_1.

Construction, fire loading characteristics, and the degree of fire protection are used to modify intrinsic dollar risk to probable dollar risk. Probable dollar risk, D, is determined twice (before and after) as with probable life risk, L, in order to obtain relative change resulting from differences in combinations of input factors. Point values are then assigned to that change in dollar risk according to Figure 2 (Section 2.2.3). The following six-step procedure is employed to calculate the change in dollar risk, ΔD.

1. Determine intrinsic dollar risk, D_1, associated with the potential fire area. Consider passive protection (horizontal and vertical fire stops) but disregard active protection (sprinklers, etc.). Include conflagration potential. Within this area determine maximum Potential Dollar Risk D_1 (at replacement cost) including approximate content value.

2. Assign an index number from Table IV according to construction and fire loading.

TABLE IV CONSTRUCTION-FIRE LOADING INDEX

		Construction		
		Fire Resistive	Heavy Timber, One-Hour Protected Non-Combustible	Ordinary Wood Frame Non-Protected Non-Combustible
*Fire Loading	Light	1	1	2
	Moderate	2	2	3
	Heavy	4	5	6

*Examples:

Light: Up to 15 pounds per square foot combustible loading, e.g., Hospitals, offices, auditoriums, schools, theaters and barracks.

Moderate: 15 to 40 pounds per square foot combustible loading, e.g. Manufacturing, repair or maintenance shops, multi-unit dwellings, exchanges, garages and other occupancies not classed as light or heavy.

Heavy: Greater than 40 pounds per square foot combustible loading, e.g., Processing or storage of flammable liquids, supply warehouses and aircraft hangars.

3. Find a percentage from Table V using the index number from Table IV and the level of protection in the facility.

4. Multiply D_1 by the percentage selected from Table V to obtain D.

5. Assume the recommendations were implemented. Then, repeat steps 1. through 4. to determine D, After.

6. Determine the difference between D Before and D After from steps 4. and 5. respectively to obtain ΔD.

Note: ΔD results from changes affecting steps 1. and/or 3. depending on the nature of the recommendation. It is possible for no change to occur.

2.2.2.4 Fire Frequency - The incidence of fire is considered a random variable for any particular facility, but the rate of occurrence (in terms of number of fire starts per unit area per time period) varies for different types of property and occupancies. Recognition of different frequencies of occurrence can be achieved by giving Navy property and occupancies (as classified in OPNAVINST 11320.25) numerical ratings based on observed fire frequencies in similar industrial property and occupancies.

TABLE V DOLLAR RISK MULTIPLIERS (%)

Construction - Fire Loading Index	Protection: None	Fire Dept. Only	Extremely Inadequate Installed Protection Only	Inadequate Installed Protection Only	Extremely Inadequate Installed Protection Plus Fire Dept.	Inadequate Installed Protection Plus Fire Dept.	Adequate Installed Protection Only	Adequate Installed Protection Plus Fire Dept.
1	50	40	46	33	38	26	8	5
2	60	48	57	40	46	31	10	6
3	65	52	62	43	50	34	11	7
4	75	60	71	50	58	39	13	8
5	85	70	81	57	66	44	14	10
6	100	88	95	68	84	54	15	12

Definitions:

Adequate: Meeting essential Navy criteria (or appropriate national codes where Navy criteria are lacking).

Inadequate: Not meeting essential Navy criteria (or appropriate national codes), but considered to have some significant installed protection (e.g. fully sprinklered with inadequate water supply, or partially sprinklered where full sprinklering is required).

Extremely Inadequate: Existing installed protection is judged to be insignificant or approaching insignificance (e.g. sprinklers with very poor water supply, or occupant operated protection in a location where sprinklers are required by criteria).

Installed: Automatic and occupant operated protection, including alarm systems .

The range of frequencies has been divided into three partitions; low, medium and high. These partitions correspond to observed frequencies of less than one fire per million square feet per year, one to three fires per million square feet per year, and greater than three fires per million square feet per year and are assigned numerical ratings of 1.0, 1.1, and 1.2 respectively. These numerical values are used as part of a specific ranking formula (Section 2.2.3) to reflect frequency as a variable measure affecting priorities for recommendations. When a fire area under consideration for recommendation includes different types of property or occupancies, the rating will be based on the predominating rating in terms of floor area.

The following frequency rating guide is used for approximation of Navy property classifications.

TABLE VI FREQUENCY RATING GUIDE

Type of Property or Occupancy	Fire Frequency Rating
Aerospace manufacturing, assembly and modification	1.1
Auto garage (dwelling)	1.2
Automotive gasoline service station	1.2
Barracks	1.2
BOQ's	1.2
Church - Chapels	1.1
Clubs	
- Officers	1.2
- CPO	1.2
- EM	1.2
Cold storage and/or refrigeration plant	1.1
Communications	1.0
Dispensary and/or dental clinics	1.0
Drydocks	1.1
Engine test cells	1.2
Electronicdata processing	1.0
Flammable Liquids and gases, handling and/or storage	1.2
Hangars	1.2
Hospitals	
- Other than wards and surgery	
- Surgery	
- Wards	1.0
Laboratories, other than medical	1.2
Laundries and/or drycleaning	1.1
Magazine, ordnance and/or chemical storage	1.2
Manufacturing, processing, industrial	1.1
Offices, administration, etc.	1.0
Mess hall and/or galley	1.1

TABLE VI (continued)

Type of Property or Occupancy	Fire Frequency Rating
Cafeteria	1.1
Outside or open storage	1.0
Ordnance manufacturing, assembly and modification	1.2
Piers-wharves	1.0
Prisoners' housing and detention	1.0
Power, heat, utilities	1.2
Dwellings	
- Multifamily	1.2
- Duplex	1.2
- Single family	1.2
- Trailers	1.2
Recreation - gymnasium, bowling alley, etc.	1.2
Child care centers and nursery	1.0
Schools - training	1.0
Shipbuilding ways	1.2
Shops	
- Hobby	1.2
- Public Works	1.0
- NARF	1.2
- Others	1.1
Stores, commissary, exchanges	1.1
Theatres	1.1
Vacant buildings	1.0
Vehicles and mobile equipment	1.0
Warehouses, storehouses - supply	1.0
Miscellaneous small outlying structures	1.0

2.2.2.5 Recommendation Cost - The cost of the proposed improvement can be estimated by the field engineer. It is expected that the estimates will normally range from approximately $10,000 to $200,000. The estimated dollar cost will be used as an input to the ranking rule formula (Section 2.2.3) to measure the cost-benefit aspect of the recommendation. The nominal dollar figures are operated upon mathematically in order to bring the cost impact into proper balance with the other factors.

2.2.3 Ranking Rule for Combining Point Values

The methodology as presented in Section 2.2.2 may stand independently as a field procedure for evaluating fire protection recommendations. Of course, improved data may warrant changes in the numbers used to assign credit to different variables but the procedure itself will remain the same.

The methodology produces a quantity of data which must be combined in such a way as to produce a single unit of measure. The ranking rule provides the means to do so. It operates on the following variables generated by the methodology.

S , Strategic Importance: A rating from 0 to 10 (2.2.2.1).

L_1, Intrinsic Life Risk: The number of personnel associated with a fire area at any time (2.2.2.2).

ΔL, Change in Probable Life Risk: The difference in probable life risk resulting from implementation of the recommendation (2.2.2.2).

D_1, Intrinsic Dollar Risk: The value of a fire area including contents (2.2.2.3).

ΔD, Change in Probable Dollar Risk: The difference in probable dollar risk resulting from implementation of the recommendation (2.2.2.3).

C , Cost: The estimated cost of the proposed improvement.

F , Frequency: The predominant rating, 1.0, 1.1, 1.2, assigned.

Variables are operated on by mathematical mappings or functions and combined to yield a final ranking number which is used to evaluate the relative merit of recommendations under consideration. The use of graphs and tables obviates all but a few simple calculations in applying the methodology and deriving the required ranking number.

The objective of a ranking rule is to provide weightings to variables such that the rankings generated are realistic, rational and consistent with the composite of the best technical judgment available. The basis for such rankings must, however, be subjective. There are no natural laws which can define such a system. Individual differences in utility and philosophy have traditionally resulted in diverse conclusions. There are, therefore, many possible ways of weighting and combining variables but finding a way which achieves the objective is difficult. After careful consideration of the variables involved, it was decided that S, ΔL and ΔD must be balanced with respect to the maximum impact each could exercise. L_1 and D_1 as intrinsic measures of risk must be balanced but with significantly less weight. The functions used give substantially greater weight to large changes in risk or high strategic value. In addition, those cases involving substantial intrinsic value but relatively small risk reduction cannot be ignored. The cost function must not be allowed to overload the ranking rule yet must exert reasonable influence. With the aid of a computer, much experimentation was conducted using different functions over varied ranges. It was decided that the ranges for ΔL and ΔD should be broken into segments. Different functions for each segment would allow different rates of change and greater control of variable impact over the entire range. The ranking rule used can be represented by the generalized formula:

$$R = f(F)\, f(C)\, \left(f(S) + f(L_1) + f(D_1) + f(\Delta L) + f(\Delta D)\right)$$

where R = ranking number*

Following are the specific mathematical mappings and functions decided upon for substitution in the generalized formula.

$f(S) = 10S^2$ (Table VII)

$f(L_1)$: Readout from Table VIII

$f(D_1)$: Readout from Table IX

$$f(\Delta L) = (\Delta L)^{3/2} \text{ for } 0 \leq \Delta L < 50$$
$$= 100 + 5L \text{ for } 50 \leq \Delta L \leq 180$$
$$= 1000 \text{ for } \Delta L > 180$$

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*The theoretical maximum for R = 3677, but it is unlikely that real situations will generate more than 652 points for recommendations which do not require the special treatment described in Sections 2.3.2 and 2.3.3.

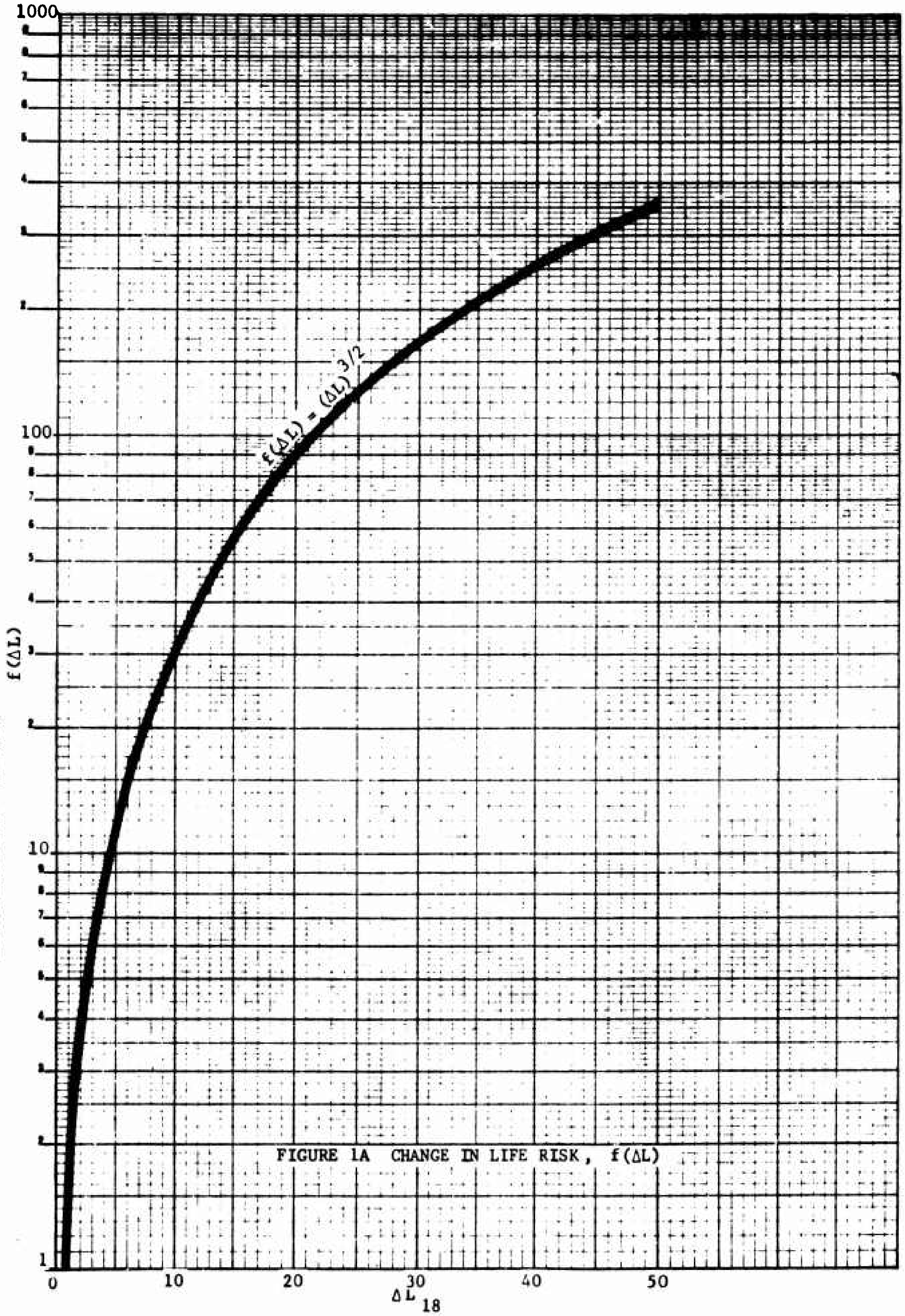

FIGURE 1A CHANGE IN LIFE RISK, f(ΔL)

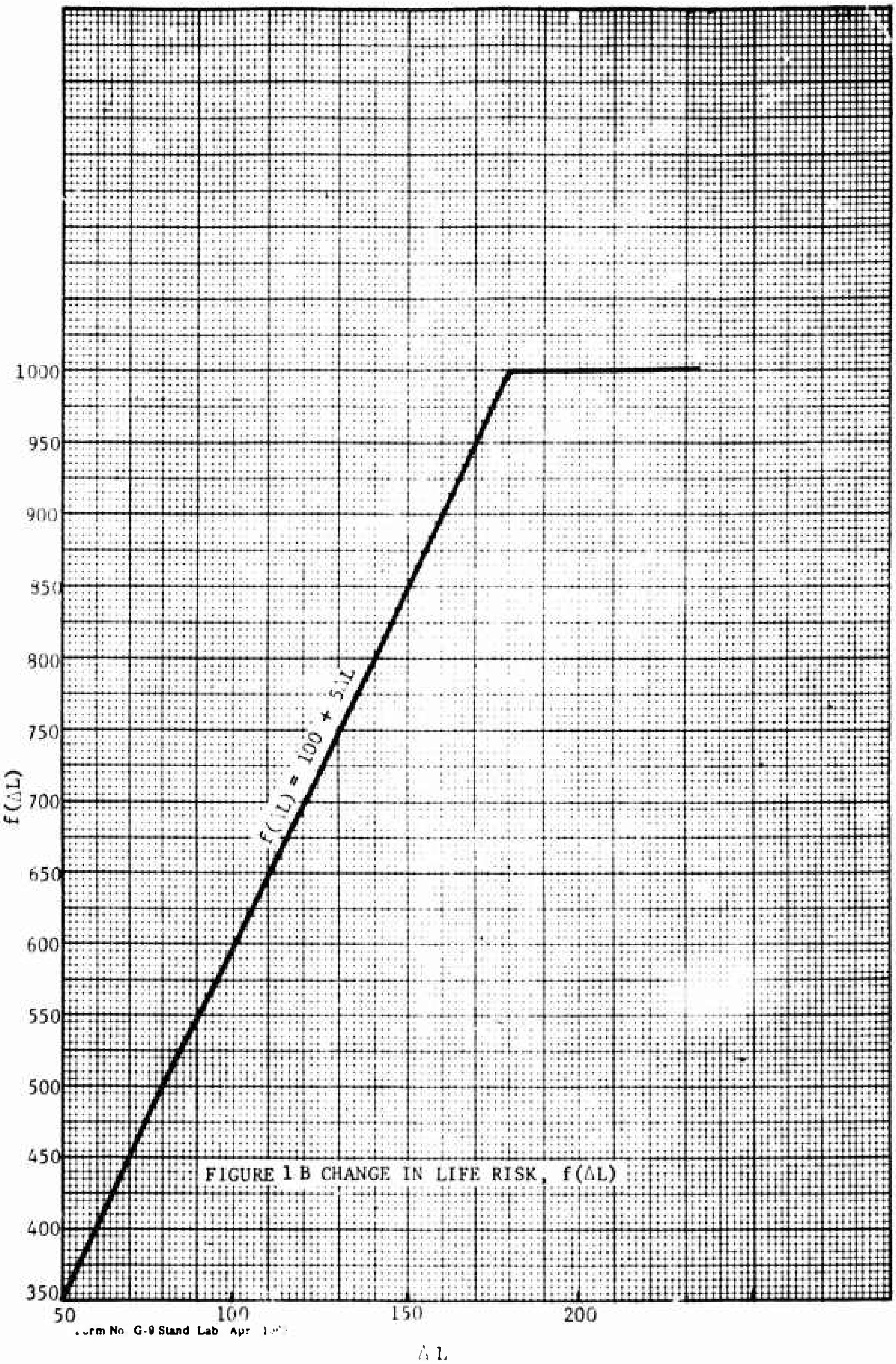

FIGURE 1 B CHANGE IN LIFE RISK, f(ΔL)

Factory Mutual Engineering Division

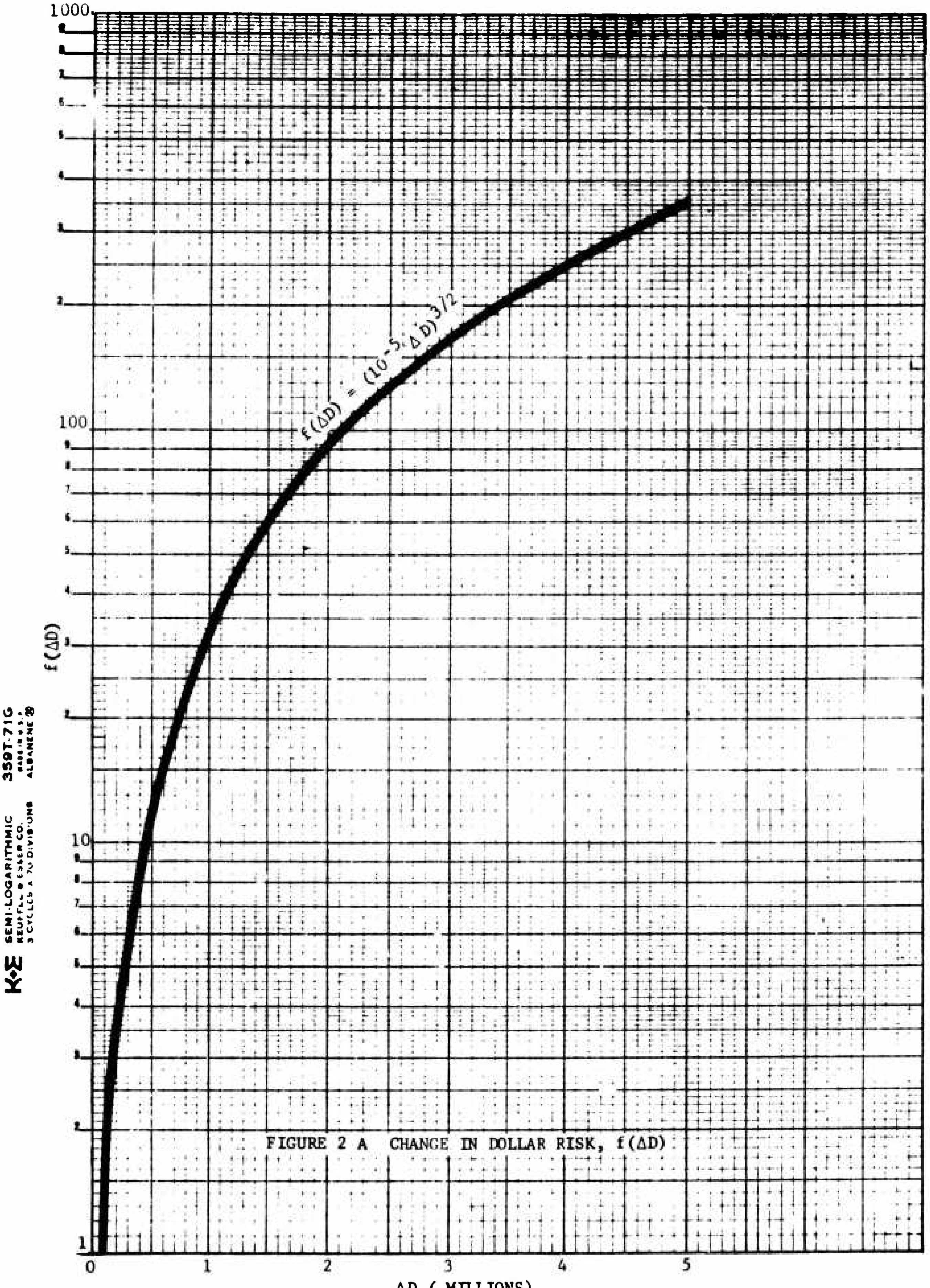

FIGURE 2 A CHANGE IN DOLLAR RISK, f (ΔD)

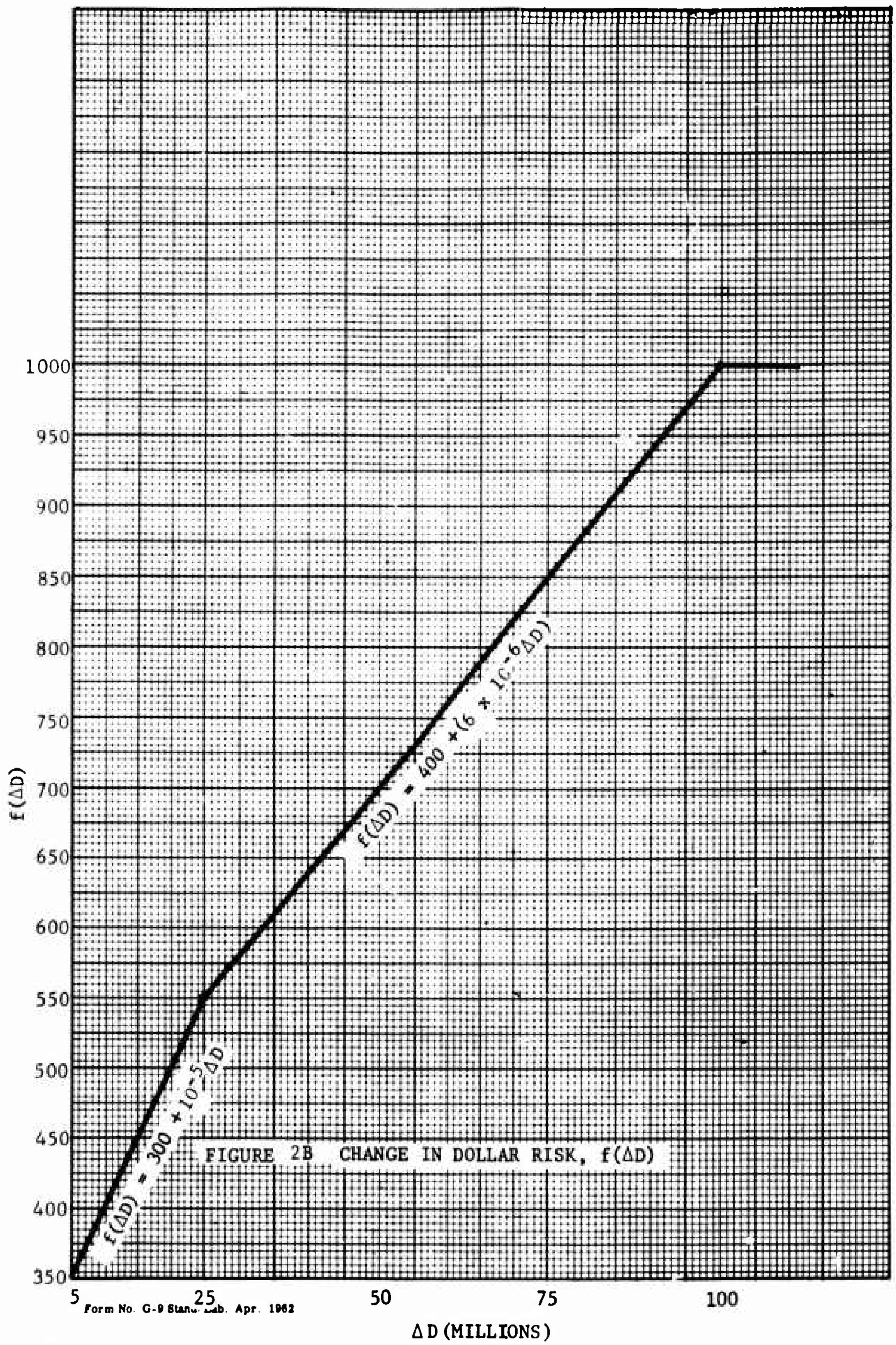

FIGURE 2B CHANGE IN DOLLAR RISK, f(ΔD)

Figure 1 provides readout for f (ΔL)

$$f(\Delta D) = (10^{-5}\Delta D)^{3/2} \quad \text{for } .1M \leq \Delta D < 5M$$
$$= 300 + 10^{-5}\Delta D \quad \text{for } 5M \leq \Delta D < 25M$$
$$= 400 + (6 \times 10^{-6})\Delta D \quad \text{for } 25M \leq \Delta D < 100M$$
$$= 1000 \quad \text{for } \Delta D \geq 100M$$
$$= 0 \quad \text{for } \Delta D < .1M$$

Figure 2 provides readout for f (ΔD)

f (F) = (1.0,1.1,1.2) from Table VI

$$f(C) = \frac{21.5}{C^{1/3}} \text{ for } 10K < C \leq 200K$$

for $C \leq 10K$, f (C) = 1 for $C \geq 200K$, f(C) = .368

Figure ' provides combined readout for f (F) f (C)

Ranking results using these formulae are consistent with this objective. It would be a mistake, however, to regard the formulae as rigidly fixed. Data gathered in the course of using this system may dictate changes to be made in the functions. Such changes would not compromise the methodology. It would be a simple matter to adjust the rankings of existing recommendations and continue setting priorities according to a revised ranking rule.

For a given example, the substitution of functions into the generalized formula may take the following form.

$$R = K_1(21.5C)^{-1/3} \left(10S^2 + K_2 + K_3 + (\Delta L)^{3/2} + (10^{-5}\Delta D)^{3/2}\right)$$

where: K_1 is f (F) obtained from Table VI
K_2 is f (L_1) from Table VIII
K_3 is f (D_1) from Table IX.

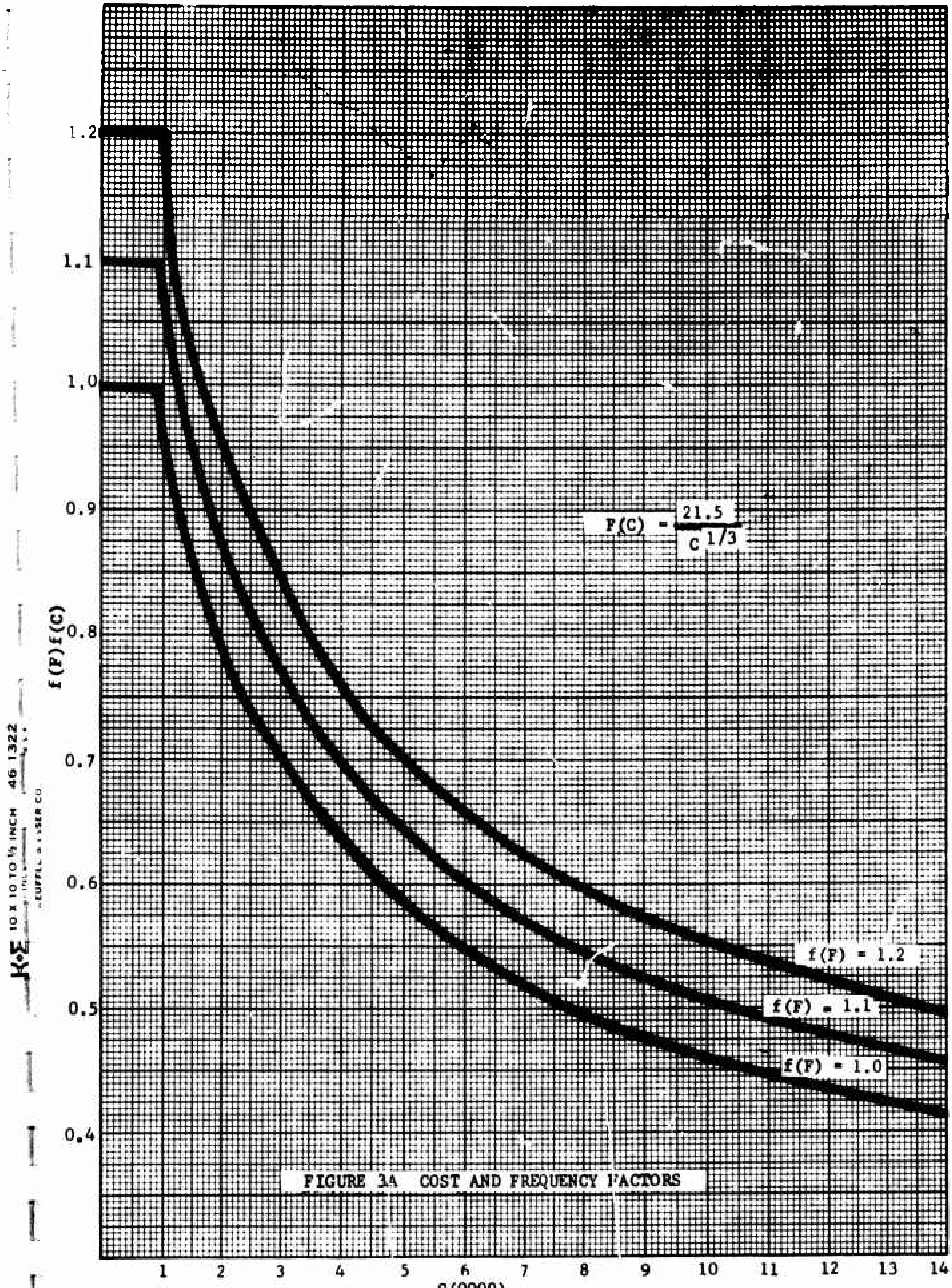

FIGURE 3A COST AND FREQUENCY FACTORS

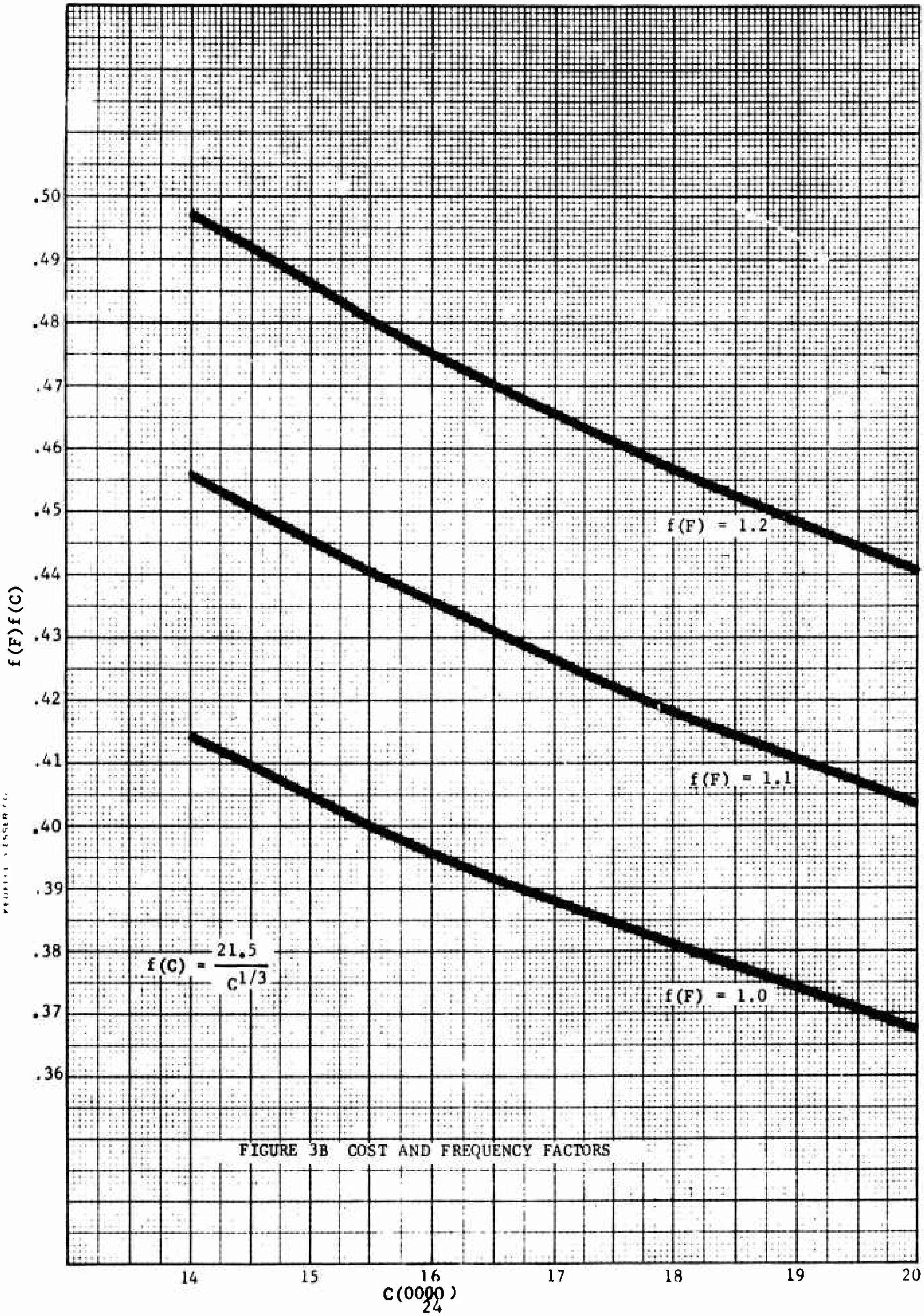

FIGURE 3B COST AND FREQUENCY FACTORS

TABLE VII

STRATEGIC IMPORTANCE, S

S	f(S)
0	0
1	10
2	40
3	90
4	160
5	250
6	360
7	490
8	640
9	810
10	1000

TABLE VIII

INTRINSIC LIFE RISK, L_1

L_1	f (L_1)
0	0
1-10	1
11-20	3
21-30	5
31-40	8
41-50	11
51-60	15
61-70	19
71-80	23
81-90	27
≥91	32

TABLE IX

INTRINSIC DOLLAR RISK, D_1

D_1(000)	f (D_1)
0-99	0
100-300	1
301-500	3
601-900	5
901-1200	8
1201-1500	11
1501-1800	15
1801-2100	19
2101-2400	23
2401-2700	27
≥ 2701	32

2.2.4 Cut-Off Rule

Primary goals of this system are to direct attention to large loss possibilities and to provide a rational, objective basis for making or not making fire protection recommendations as warranted.

Based on a field sample and after considerable thought and experimentation a cut-off rule was developed to facilitate the decision-making process. The rule is as follows:

If $S \leq 4$ (i.e. $f(S) \leq 160$) and the summation $f(L_1) + f(D_1) + f(\Delta L) + f(\Delta D) \leq 62$, then no further consideration should be given to the recommendation.

2.2.5 Summary of Methodology

The application of the methodology involves the determination of, at most, 13 pieces of data. First, the facility is considered as it exists and five numbers must be found for the five factors, S, L_1, ΔL, D_1 and ΔD. The potential fire area (disregarding installed active protection) must be estimated, including conflagration potential. Any fire department which serves the facility will be considered to operate normally. For the purposes of this procedure, the effects of the fire department on potential fire area are in limiting the fire to the building of origin, or limiting the fire spread to some conservative extent. Once the potential fire area is established, the strategic importance of the area should be rated (according to the surveyor's knowledge and information from the activity command) and intrinsic life and dollar risk determined. Intrinsic life risk, L_1, is represented by the maximum number of personnel associated with the fire area. Intrinsic dollar risk, D_1, is represented by the dollar replacement cost of the fire area including building and contents. Using the table relating condition of occupants with protection and personnel firesafety standards, the surveyor finds a percentage which is used to reduce intrinsic, L_1, to probable life risk, L. In two similar operations, D_1 is reduced to a probable dollar risk, D. An index number is first obtained from Table IV relating construction and fire loading. A percentage is then found from Table V relating that index number to various levels of fire protection.

Second, the facility is reconsidered as though the recommendation had been implemented. The potential fire area must again be estimated, since a recommendation for passive protection could cause significant change. A recommendation dealing entirely with installed active protection would not change potential fire area since, for this calculation, such protection is disregarded. If the potential fire area has changed, intrinsic life risk, L_1, and dollar risk, D_1, associated with that area must be redetermined. If passive protection would cause the division of the original potential fire area, then the highest value of L_1 for any division and the highest value of D_1 for any division will be used. For either active or passive protection recommendation, L_1 and D_1 values are again adjusted using the tables, this time assuming the recommendation had been implemented. In this way "after" measures of L and D are generated.

The third step is simply the determination of the change in risk. This change is obtained by subtracting "after" values of L and D from the "before" values.

The values for the variables S, the original L_1 and D_1 and the changes ΔL and ΔD, due to the implemented recommendation are converted to point values. A cut-off rule is then applied to determine if the recommendation should receive further consideration.

For recommendations receiving further consideration, frequency, F, is found based upon the predominating type of property or occupancy and cost, C, is determined by estimating the cost of the proposed improvement. F and C determine a multiplier to be applied to the summation of the point values generated for S, L_1, D_1, ΔL and ΔD. Thus, a ranking number, R, is calculated according to the following generalized formula:

$$R = f(F)\, f(C) \left(f(S) + f(L_1) + f(D_1) + f(\Delta L) + f(\Delta D)\right)$$

As experience or changes in philosophy dictate, the functions of different variables in the ranking formula may be changed, as may the formula itself and the cut-off rule. In addition to being amenable to automatic data processing, the methodology and formula have built-in flexibility to allow for whatever adjustments are necessary based on the acquisition of more and better information and on the needs of the Navy.

2.3 DISCUSSION OF APPLICABILITY

2.3.1 Introduction

The basic methodology as defined in Section 2.2 was determined to be applicable with little difficulty to the majority of fire protection deficiencies existing at Navy installations by an extensive field testing effort discussed in Section III. The nature of the methodology is such that it is structure oriented. It is primarily designed to handle recommendations dealing with a specific building or structure on shore. Since most deficiencies fall within that category it was logical to define the system to easily handle these cases. However, as was the case with the first generation methodology, this type of basic system format is not capable of handling less frequently encountered special cases. Specifically, these latter cases deal with 1) pier water supply deficiencies for shipboard protection and 2) widespread water or alarm projects which could affect a large number of structures. In order to handle these special cases, special rules are defined in Sections 2.3.2 and 2.3.3.

2.3.2 Treatment of Ship Protection Recommendations

As previously indicated, deficiencies, as determined from Table 3.3 (Shore Services Water) of NAVFAC DM-25, cannot be handled directly by the methodology. There is no realistic way to determine ΔL or ΔD since the relationship between available shore water and the expected loss (for different types of vessels) in the event of a fire has never been even generally defined. The difficulty becomes even more pronounced if one considers the different modes in which the vessels may reside: wet berth; normal or cold iron; and dry dock. This variable can affect the change of many significant parameters. In fact, it is the opinion of the authors that the expected loss is as much a function of other parameters germane to the vessel as of the current requirements for shore services water.

Although NAVSHIPS is presently considering the overall shore services water problem, this application requires a special means to handle these deficiencies. After lengthy discussion with Navy personnel, it was decided that an arbitrary point assignment procedure would be used. To aid in the assignment of points, the following conclusions were provided for FMRC:

1) with the exception of a few auxiliary ships, vessels cannot be classified into distinct groups of importance;
2) since the basic function of the Navy is to keep the fleets operational, vessels, by definition, must demand the maximum rating for strategic importance;
3) the dollar values associated with vessels are significantly higher than would be expected for shore structures;
4) the life exposure associated with vessels would be as high as the maximum expected for shore structures;
5) due to the overwhelming impact of items 1-4, the fact that it is not possible to make an assessment of risk reduction (before and after) should be insignificant for ranking purposes.

Based upon these conclusions, it was agreed that the following special procedure would be applied. Protection for ships should receive maximum point value (3677) where water flow deficiencies are greater than 25% of the amount required. Where deficiencies are less than 25% but greater than 10%, 600 points should be assigned. Deficiencies less than 10% are recognized but considered acceptable until better data is available.

2.3.3 Treatment of Activity-Wide Recommendations

Since deficiencies associated with water supply or alarm systems usually affect a number of buildings, special rules must again be defined to allow a simple and economical application of methodology to provide a relative ranking. It is clear that if the entire project cost were compared against the improvement for one building, disproportionate cost penalties would probably be incurred. In order to compare the project cost against cumulative facility-wide improvement, a time consuming and costly in-depth study would be required. Such a detailed effort would tend to negate a prime advantage of the methodology: that it does not require significantly more time than is presently spent during the field survey. After thorough discussion with Navy personnel, a compromise between these two extremes was selected as a reasonable solution. Whenever a recommendation affects more than one structure, the basic methodology (Section 2.2) is to be applied to the affected structure which is considered to be the most important to Navy operations. For a cost estimate, the total project cost is to be divided by the total number of important structures considered to be improved significantly. Clearly, the underscored words indicate more value judgment will be required of the surveyor than is necessary in any other application of the methodology. However, this procedure is considered acceptable since the number of structures actually processed through the methodology is thereby minimized and such special cases can be handled logically and economically.

III

FIELD TESTING

3.1 INTRODUCTION

In order to evaluate the ease, flexibility, and time of methodology application, field testing was conducted at Western Division Naval Facilities Engineering Command. Existing fire protection recommendations were used to pinpoint deficiencies. Approximately forty recommendations were processed through the methodology. These recommendations had been generated at Hunters Point Naval Shipyard, Alameda Naval Air Station, Alameda Naval Air Rework Facility, Oakland Naval Supply Center, Mare Island Naval Shipyard, North Island Naval Air Station and North Island Naval Air Rework Facility. The input variables required for the methodology were acquired on site with NavFac personnel participating. Difficulties associated with the interpretation and application of the methodology were discussed at the Naval facilities and again in group meetings at the Western Division office. These field surveys and discussions provided the feedback necessary for general improvement and the elimination of minor difficulties, inconsistencies and shortcomings.

The following cases (Section 3.2) are not an inclusive set of all recommendations processed through the methodology. The intent is to provide a cross section of distinct examples for the application of the methodology.

3.2 EXAMPLES

1. LOCATION: NSC OAKLAND

Recommendation A-3-67

"Install automatic sprinklers in theater and gymnasium Bldg. No. 746."

Strategic Importance, S:

1. No weapons or communications system involved. Rating - 0
2. No strain on mission capability. Rating - 0

Total Rating S = 0

Intrinsic Life Risk, L_1: 175

Life Risk, L, Before:

Condition of occupants is mobile and awake. Inadequate protection but meeting personnel fire safety standards.

From Table III, L Before = 2% (175) = 4

Life Risk, L, After:

Everything remains the same except the level of protection which is upgraded to adequate.

Therefore, L After = 1% (175) = 2

Change in Probable Life Risk, ΔL:

L Before - L After = 4-2 = 2

Intrinsic Dollar Risk, D_1:

The potential fire area is determined to be the entire area of two-story building 746.

D_1 = total = \$1.2 million

Dollar Risk, D, Before:

Overall fire loading is considered to be moderate. Type of construction is wood frame. From Table IV, the index number is 3. The level of protection is extremely inadequate plus Fire Department. From Table V, D Before is, therefore, 50% (\$1.2 million) = \$600,000

Dollar Risk, D, After:

Everything remains the same except the level of protection which is upgraded to adequate plus Fire Department.

D After is, therefore, 7% (\$1.2 million) = \$84,000

Change in Probable Dollar Risk, ΔD:

D Before - D After = \$600,000 - \$72,000 = \$528,000

It is now time to convert the variables generated by the methodology into a point ranking.

$S = 0$, $f(S) = 0$ (Table VII)

$L_1 = 175$ $f(L_1) = 32$ (Table VIII)

$D_1 = \$1.2$ million, $f(D_1) = 8$ (Table IX)

$\Delta L = 2$, $f(\Delta L) = 3$ (Figure 1A)

$\Delta D = \$528$ thousand, $f(\Delta D) = 12$ (Figure 2A)

$f(L_1) + f(D_1) + f(\Delta L) + f(\Delta D) = (32 + 8 + 3 + 12) = 55$

This example does not meet the cut-off rule criteria for further consideration. However, to complete the example, R is calculated.

Recommendation Estimated Cost, C: $98,000

Frequency, F:

Occupancy type is recreation. From Table VI, $f(F) = 1.2$

$f(F)f(C) = .560$ (Figure 3A)

$R = .560(0 + 32 + 8 + 3 + 12) = 31$

2. LOCATION: NAVAL SHIP YARD, MARE ISLAND

Recommendation 6-A-68

"A standard automatic wet pipe sprinkler system should be installed in the 11,000 square foot, wood frame Teen-Age Club, building 737."

Strategic Importance, S:

1. No weapons or communications system involved. Rating - 0
2. No strain on mission capability. Rating - 0

Total Rating S = 0

Intrinsic Life Risk, L_1: 500

Life Risk, L, Before:

Condition of occupants is mobile and awake. Inadequate protection but meeting personnel fire safety standards.

From Table III, L Before = 2% (500) = 10

Life Risk, L, After:

Everything remains the same except the level of protection which is upgraded to adequate.

Therefore, L After = 1% (500) = 5

Change in Probable Life Risk, ΔL:

L Before - L After = 10 - 5 = 5

Intrinsic Dollar Risk, D_1:

The potential fire area is determined to be the entire area of building 737

Building Value	$295,000
Content Value	$ 30,000
D_1 = Total =	$325,000

Dollar Risk, D, Before:

Overall fire loading is considered to be light.
Type of construction is wood frame.
From Table IV, the index number is 2.
The level of protection is Fire Department only.
From Table V, D Before is, therefore, 48% (325,000) = $156,000

Dollar Risk, D, After:

Everything remains the same except the level of protection which is upgraded to adequate plus Fire Department.

D After is, therefore, 6% (325,000) = $19,500

Change in Probable Dollar Risk, ΔD:

D Before - D After = $156,000 - $19,500 = $136,500

It is now time to convert these variables generated by the methodology into a point ranking.

S = 0	f(S) = 0	(Table VII)
L_1 = 500	$f(L_1)$ = 32	(Table VIII)
D_1 = $325,000	$f(D_1)$ = 3	(Table IX)

$\Delta L = 5$, $f(\Delta L) = 11$ (Figure 1A)

$\Delta D = \$136{,}500$, $f(\Delta D) = 1$ (Figure 2A)

$f(L_1) + f(D_1) + f(\Delta L) + f(\Delta D) = (32 + 3 + 11 + 1) = 47$

This example does not meet the cut-off rule criteria for further consideration. However, to complete the example, R is calculated.

Recommendation Estimated Cost, C: $10,000

Frequency, F:

Occupancy type is Teen club, snack bar and dance hall.

From Table VI, $f(F) = 1.2$

$f(F)f(C) = 1.2$ (Figure 3A)

$R = 1.2(0 + 32 + 3 + 1 + 11) = 56$

3. LOCATION: NARF ALAMEDA

Recommendation B-1-71

"Standard automatic wet pipe sprinkler protection should be provided for all positions of the 40,000 sq. ft. part one-and part two-story wood frame Shop Building No. 162."

Strategic Importance, S:

1. Direct support of major weapon system. Rating - 4
2. Significant, moderate strain on activities capability; classification 2. Rating - 2

Total Rating S = 6

Intrinsic Life Risk, L_1: 200

Life Risk, L, Before:

Condition of occupants is mobile and awake.

Inadequate protection but meeting personnel fire safety standards.

From Table III, L Before = 2% (200) = 4

Life Risk, L, After:

Everything remains the same except the level of protection which is upgraded to adequate.

Therefore, L After = 1% (200) = 2

Change in Probable Life Risk, ΔL:

L Before - L After = 4 - 2 = 2

Intrinsic Dollar Risk, D_1:

The potential fire area is determined to be the entire area of Building No. 162

Building Value = 2.7 million

Content Value = 4 million

D_1 = Total = 6.7 million

Dollar Risk, D, Before:

Overall fire loading is considered to be light.

Type of construction is wood frame.

From Table IV, the index number is 2.

Since the building is partially sprinklered, the level of protection is inadequate installed protection plus Fire Department.

From Table II, D Before is, therefore,

31% ($6.7 million) = $2.07 million

Dollar Risk, D, After:

Everything remains the same except the level of protection which is upgraded to adequate plus Fire Department.

D After is, therefore, 6% ($6.7 million) = $400,000

Change in Probable Dollar Risk, ΔD:

D Before - D After = $2,070,000 - $400,000 = $1.67 million

It is now time to convert these variables generated by the methodology into a point ranking.

$S = 6$ $f(S) = 360$ (Table VII)

Since $S > 4$, this example meets the cut-off rule criteria for further consideration.

$L_1 = 200$ $f(L_1) = 32$ (Table VIII)

$D_1 = \$6.7$ million, $f(D_1) = 32$ (Table IX)

$\Delta L = 2$ $f(\Delta L) = 3$ (Figure 1A)

$\Delta D = \$1.67$ million, $f(\Delta D) = 70$ (Figure 2A)

Recommendation Estimated Cost, C: $50,000

Frequency, F:

Occupancy type is engine repair and machine shop.

From Table VI, $f(F) = 1.1$

$f(F)f(C) = .642$ (Figure 3A)

$R = .642(360 + 32 + 32 + 3 + 70) = 319$

4. LOCATION: NAVAL SHIP YARD, HUNTERS POINT

Recommendation: The following three recommendations appear separately on the FPE report which were combined into one MCON Project (P-321) programmed for FY1974. In view of this and the fact that only one structure is involved, they are treated as one for methodology processing.

A-1 (1948). "The open interior stairways in Administration Building No. 101 should be provided with one-hour enclosures which discharge directly to the outside."

A-2 (1948. "Vertical ladders on the ends of the wings of Administration Building No. 101 used for secondary means of egress should be replaced with standard fire escape stairways."

A-3 (1948). "Complete sprinkler protection should be provided in Administration Building No. 101."

Strategic Importance, S:

1. Indirect support of major weapons or communications system. Rating - 2
2. Moderate length significant strain on activity's mission capability; classification 2. Rating - 3

Total Rating S = 5

Intrinsic Life Risk, L_1: 850

Life Risk, L, Before:

Condition of occupants is mobile and awake.

Inadequate protection and dangerous departures from personnel fire safety standards.

From Table III, L Before = 9% (850) = 77

Life Risk, L, After:

Protection and personnel fire safety standards are upgraded to adequate.

Therefore, L After = 1% (850) = 9

Change in Probable Life Risk, ΔL:

L Before - L After = 77 - 9 = 68

Intrinsic Dollar Risk, D_1:

The potential fire area is determined to be the entire area of building 101 (2 stories plus basement).

Building Value = \$3.1 million

Content Value = \$2.0 million

D_1 = Total = \$5.1 million

Dollar Risk, D, Before:

Overall fire load is considered to be heavy.

Type of construction is wood frame. From Table IV, the index number is 6. The level of protection is extremely inadequate (there are a few sprinklers on the second floor) plus Fire Department.

From Table V, D Before is, therefore, 84% (\$5.1 million) = \$4,284,000

Dollar Risk, D, After:

Everything remains the same except the level of protection which is upgraded to adequate plus Fire Department.

D After is, therefore, 12% ($5.1 million) = $612,000

Change in Probable Dollar Risk, ΔD:

D Before - D After = $4,284,000 - $612,000 = $3,672,000

It is now time to convert these variables generated by the methodology into a point ranking.

$S = 5$ $f(S) = 250$ (Table VII)

Since $S > 4$, this example meets the cut-off criteria for further consideration

$L_1 = 850$ $f(L_1) = 32$ (Table VIII)

D_1 = $5.1 million, $f(D_1) = 32$ (Table IX)

$\Delta L = 68$ $f(\Delta L) = 440$ (Figure 1A)

$\Delta D = 3,672,000$ $f(\Delta D) = 220$ (Figure 2B)

Recommendation Estimated Cost, C: $369,000

Frequency, F:

Occupancy type is offices.

From Table VI, $f(F) = 1.0$

$f(F)f(C) = .368$ (minimum value for $F = 1.0$)

$R = .368\ (250 + 32 + 32 + 440 + 220) = 358$

5. LOCATION: NARF ALAMEDA

Recommendation: A-1-71

"All nonsprinklered sections of Building No. 5 including wood frame additions, mezzanines, and offices should be protected by standard installations of automatic sprinkler systems."

Recommendation: A-2-71

"Deluge sprinkler systems now existing in sections of Building No. 5 should be redesigned to utilize available water supply."

Note: Although these two recommendations appear separate on the 1971 Fire Protection Engineering Survey Report, they were combined into one large unprogrammed MCON Project (P-003). In view of this and the fact that only one structure is involved, the two recommendations are treated as one for methodology processing.

Strategic Importance, S:

1. Direct support of major weapons system. Rating - 4
2. Severe, extended strain on activity's capability; classification 4. Rating - 6

Total rating S = 10

Intrinsic Life Risk, L_1: 2000

Life Risk, L, Before:

Condition of the occupants is mobile and awake.
Inadequate protection but meeting personnel fire safety standards.
From Table III, L Before = 2% (2000) = 40

Life Risk, L, After:

Protection is upgraded to adequate.
Therefore, L After = 1% (2000) = 20

Change in Probable Life Risk, ΔL:

L Before - L After = 40 - 20 = 20

Intrinsic Dollar Risk, D_1:

The potential fire area is determined to be the entire area of the building 5 complex.

Building Value	=	$27 million
Content Value	=	20 million for equipment
		85 million for aircraft
D_1 = Total	=	$132 million

Dollar Risk, D, Before:

Overall fire loading is considered to be light. Type of construction is non-protected non-combustible. From Table IV, the index number is 2. The level of protection is inadequate installed protection plus Fire Department.

From Table V, D Before is, therefore, 31% ($132 million) = $41 million.

Dollar Risk, D, After:

Everything remains the same except the level of protection which is upgraded to adequate plus Fire Department.

D After is, therefore, 6% (132 million) = $8 million

Change in Probable Dollar Risk, ΔD:

D Before - D After = $41 million - $8 million = $33 million

It is now time to convert these variables generated by the methodology into a point ranking.

S = 10 f(S) = 1000 (Table VII)

Since S > 4, this example meets the cut-off criteria for further consideration.

L_1 = 2000	$f(L_1)$ = 32	(Table VIII)
D_1 = $132 million	$f(D_1)$ = 32	(Table IX)
ΔL = 20, f(L)	f(ΔL) = 90	(Figure 1A)
ΔD = $33 million	f(ΔD) = 598	(Figure 2B)

Recommendation Estimated Cost, C: $2,000,000

Frequency, F:

Occupancy type is primarily aircraft manufacturing and overhaul. Office areas on mezzanine levels.

From Table VI, f(F) = 1.1

f(F)f(C) = .405 (minimum value for F = 1.1)

R = .405 (1000 + 32 + 32 + 90 + 598) = 710

6. LOCATION: NSC OAKLAND

Recommendation B-1-64(Rev. 71)

"Install approved type cut-offs and fire protection in the horizontal and vertical conveyor openings in fire walls and/or floors of storehouse Bldg. Nos. 312, 313, 413, and 421."

Note: On recommendations such as this* which combine similar deficiencies for more than one structure into a single item on the FPE Survey Report, each separate structure should be evaluated individually. For this type of recommendation (unlike facility-wide improvement recommendations), it is relatively easy to determine all methodology input variables needed for processing for each structure. In cases where the structures are not significantly different, the ranking value, R, for one of the structures can be used as an estimator for the others. Hence, if the estimator is below the cut-off value, it can be assumed the others will also be below the cut-off.

Since this example serves only as an instructive exercise, only one structure, sprinklered Bldg. No. 313 is presented.

Strategic Importance, S:

1. Indirect support of major weapons or communications systems. Rating - 2
2. Moderate length severe strain on activity's mission capability; classification 3. Rating - 5

Total Rating S = 7

Intrinsic Life Risk, L_1: 17 (total number of people on 6 floors)

Life Risk, L, Before:

Condition of occupants is mobile and awake.

Inadequate protection but meeting personnel safety standards.

From Table III, L Before = 2% (17) = 0

*A similar recommendation which appears frequently is: Install automatic sprinklers in Warehouse Building Nos. W, X, Y and Z.

Life Risk, L, After:

Since L Before is zero, then L After must also be zero. However, since these examples are presented for instructional purposes, the following should be noted. This recommendation includes both active and passive protection. By implementing the recommendation the potential fire area and the associated number of people would be reduced, in this case from 17 to 2. The level of protection would also change to adequate. L After would, therefore, be calculated by 1% (2) = 0. Under other conditions, this could result in a significant change. The same logic is again applied for the calculation of D After.

Change in Probable Life Risk, ΔL:

L Before - L After = 0 - 0 = 0

Intrinsic Dollar Risk, D_1:

The potential fire area is determined to be the entire area of the six-story building No. 313. Because of sufficient separation, it is unlikely that the conveyors which connect two adjacent structures would cause the involvement of these buildings in the event of a fire.

Building Value = \$ 4 million
Content Value = 30 million
D_1 total = \$34 million

Dollar Risk, D, Before:

Overall fire loading is considered to be moderate. Type of construction is fire resistive. From Table IV, the index number is 2. The level of protection is inadequate plus Fire Department.
From Table V, D Before is, therefore, 31% (\$34 million) = \$10,540,000

Dollar Risk, D, After:

Since the passive protection would effectively partition the building into 12 segments, the potential fire area would then be 1/12 of the structure. Consequently, the dollar value associated with that fire area would be (\$34 million ÷ 12) = \$2.8 million. In addition, the protection would be upgraded to adequate plus Fire Department.
D After is, therefore, 6% (\$2.8 million) = \$168,000

Change in Probable Dollar Risk, ΔD:

D Before - D After = \$10,540,000 - \$168,000 = \$10,372,000

It is now time to convert these variables generated by the methodology into a point ranking.

$S = 7$ $f(S) = 490$ (Table VII)

Since $S > 4$, this example meets the cut-off criteria for further consideration.

$L_1 = 17$ $f(L_1) = 3$ (Table VIII)

D_1 = \$34 million, $f(D_1) = 32$ (Table IX)

$\Delta L = 0$ $f(\Delta L) = 0$

ΔD = \$10,372,000, $f(\Delta D) = 403$ (Figure 2B)

Recommendation Estimated Cost, C: \$65,000

Frequency, F:

Occupancy type is warehouse.

From Table VI, $f(F) = 1.0$

$f(F)f(C) = .535$ (Figure 3A)

$R = .535(490 + 3 + 32 + 0 + 403) = 496$

7. LOCATION: NAVAL AIR STATION, NORTH ISLAND

Recommendation: The following special projects request (No. R22-72) deals with a facility-wide water distribution system improvement which would have an effect on many structures. It is presented here to exemplify the use of the special rules to handle such a recommendation.

"This project will clean and cement-line 140,650 LF of 4" to 20" cast iron fresh (potable) water main. 58,900 LF of 2" to 10" cast iron salt water main will be removed and replaced with cement asbestos pipe. The salt water system will be converted to fresh water."

At this point, it is necessary to decide upon one structure for which the variables are determined. This structure should be the most important to Navy operations at the facility. In this case, building 94, a NARF aircraft assembly plant, with second story office area, clearly fits that description. It is not, however, presently one of the 34 buildings equipped with automatic sprinklers, although a separate recommendation exists for this installation. For purposes of this exercise, it is assumed that the sprinklers are installed prior to this special project's implementation. Building 94, for the following calculations, is assumed to presently have inadequate installed protection similar to the other 34 sprinklered structures.

Stragetic Importance, S:

1. Direct support of major weapons system. Rating - 4
2. Extended duration, severe strain or activity's mission capability; classification 3. Rating - 6

Total Rating S = 10

Intrinsic Life Risk, L_1: 1500

Life Risk, L, Before:

Condition of the 1000 assembly workers on the first floor is mobile and awake. The 425 office workers on the first floor and 75 on the second floor are in extremely overcrowded situations, people, furniture, and storage. Because there are a large number of people involved on each floor and conditions are different, L Before will be calculated for each occupancy type and combined. Inadequate protection and potentially dangerous departures from personnel fire safety standards exist for the office workers. In addition to being overcrowded, inadequate exits exist. Inadequate protection but meeting personnel fire safety standards exist for the assembly workers.

From Table III, L Before = 20% (500) + 2% (1000) = 120

Life Risk, L, After:

Everything remains the same except the level of protection is upgraded to adequate.

Therefore, L After = 12% (500) + 1% (1000) = 70

Change in Probable Life Risk, ΔL:

L Before - L After = 120-70 = 50

Intrinsic Dollar Risk, D_1:

The potential fire area is determined to be the entire area of building No. 94.

Building Value = $ 5 million
Content Value = 250 million
D_1 = Total = $255 million

Dollar Risk, D, Before:

Overall fire loading is considered to be moderate. Type of construction is non-protected noncombustible. From Table IV, the index number is 3. The level of protection is inadequate installed protection plus Fire Department.

From Table V, D Before is, therefore, = 34% ($255 million) = $86,700,000

Dollar Risk, D, After:

Everything remains the same except the level of protection which is upgraded to adequate plus Fire Department.

D After is, therefore, = 7% ($255 million) = $17,850,000

Change in Probable Dollar Risk, ΔD:

D Before - D After = $86,700,000-$17,850,000 = $68,850,000

It is now time to convert these variables generated by the methodology into point ranking.

S = 10 f(S) = 1000 (Table VII)

Since $S > 4$, this example meets the cut-off criteria for further consideration.

L_1 = 1500 $f(L_1)$ = 32 (Table VIII)
D_1 = $255 million, $f(D_1)$ = 32 (Table IX)
ΔL = 50 f(ΔL) = 350 (Figure 1B)
ΔD = $68,850,000, f(ΔD) = 813 (Figure 2B)

Recommendation Estimated Cost, C: The estimated cost of this special project is $1,682,000. For this example, as indicated in section 2.3.3, the cost must be divided by the total number of important structures considered to be significantly improved. 34 of 62 buildings are completely sprinklered (other than those on two separate high pressure water systems) at North Island. All 34 of these structures are considered important. Due to the extremely poor sprinkler system reliability resulting from water main breaks under higher pressure (booster pumps) fire emergency situations, all are considered to be significantly improved. Therefore, C is calculated for this example by dividing 1,682,000 by 34. Hence, C = $49,500.

Frequency, F:

Occupancy type is primarily aircraft assembly.
From Table VI, $f(F) = 1.1$

$f(F)f(C) = .644$ (Figure 3A)
$R = .644(1000 + 32 + 32 + 350 + 813) = 1434$

Note: If the previous calculation were actually made for the recommendation for installing automatic sprinklers in building No. 94, only two variable values would change.

1. C would be equal to the estimated cost of the sprinkler system installatwon.
2. D Before would be calculated on the basis of Fire Department only.

IV

DATA DEFICIENCIES

It is essential to the ultimate success of the risk management system that information be recorded in the proper form for review. The existence of such information is prerequisite to adjustment of the tables of frequency and risk to reflect Navy experience.

It is recommended that a scoresheet be designed as part of, or appendix to, the FPE Survey Report (NavMat 11320-2). Such scoresheets, incorporating the input variables for the methodology, would provide a framework to aid in the systematic application of the methodology. In addition, they would provide an internal record of the potential risks and associated characteristics, including the level of protection existing, the number of personnel involved, and the strategic considerations encountered. With such a record, basic changes in the system or in its tables and graphs could be tested on real facilities and situations noting the impact of such changes on the ranking of recommendations. Of course, such information should be encoded to allow machine tabulation.

Fire loss reports should provide for recording for machine use of total floor area, building and contents replacement values, size of the potential fire area and its occupancy and associated intrinsic life and dollar risks. Presently, the damage to buildings is calculated by taking the ratio (cost of repairs/replacement value) and multiplying this by the plant account value. The resulting number is recorded for electronic data processing. In accordance with this suggestion: that building and contents replacement values be used; it is recommended that damage to buildings and contents also be recorded as dollar amounts and percentages of replacement values. If practical, the Real Property Inventory code number and combustibles involved in the loss should also be encoded. Thus, a record of Navy losses by occupancy as a percentage of the potential for each loss could be generated. This distribution of losses could be incorporated into future versions of the system. The level of protection existing for the fire area in which the loss incident occurs should also be encoded to allow observation of the effect afforded by different levels of protection.

It does not appear practical or entirely necessary to revise the Inventory of Naval Shore Facilities at this time. Existing shortcomings are the inability to partition the data to establish the population of specific risks from which losses occur, and the total lack of some data relevant to fire protection considerations. These shortcomings are partially due to 1) the fact that the inventory categories are not perfectly reconcilable to the categories that are relevant to fire protection 2) and partly due to the inability to foretell the future with respect to data needs. It is believed that the suggestions made for coding information on the FPE Survey Reports and the Fire Loss Reports will provide needed data to apply and modify the system.

V

APPLICABILITY OF METHODOLOGY TO NAVY FIRE PROTECTION CRITERIA

The Navy applies a mixture of Naval and industrial criteria when dealing with fire risk. It is a hard fact of economic limitations in fire protection resources that many recommendations are simply exercises in paper work that will never become anything more. One aim of this system of risk analysis is to allow the Navy to define and identify the risks itwill be accepting. A further goal is to allow the products of this risk analysis methodology to aid in the development of criteria specifically for Navy application in the systematic management of risk. Recognizing that there will never be enough fire protection funding to do all that present criteria require, the best that can be expected is to put each fire protection dollar to work where it will do the most good. For the present, this means allocating funds on the basis of rankings generated by the system. For the future the possibilities are more diversified.

Historical data which the methodology will provide may be used to identify categorically certain classes of risk and certain types of recommendations which should not be given consideration either independently or in combination. The loss expectancy and overall value (S, L_1, D_1) of some facilities and/or the benefits to be obtained from certain types of recommendations may be shown not to warrant consideration. In that event, criteria would be written, in effect, to accept certain risks or attempt to deal with them by a different method. For example, data may indicate that facilities of type X with overall value less than Y should not be considered at all. In some cases the emphasis might be shifted to passive protection which would divide a large risk into smaller, acceptable risks; in such cases, criteria for active installed protection would not apply. The establishment and periodic reevaluation of cut-off points is also a systematic way of applying the methodology to Navy fire protection criteria. The reverse of this procedure, that is, use of the methodology to identify large loss potentials, may serve to generate criteria for specifying facilities to receive concentrated attention as risks which cannot be assumed.

Eventually, data from this methodology may lead to finer distinctions than the boundary conditions referred to above (i.e., cut-off points). For example, the data may indicate for specific types of occupancies, the value ranges which need to be inspected and those which do not (i.e., those which are not worth a recommendation or where a sufficiently good loss record exists to warrant accepting the risk). The data may also indicate which occupancies should be governed by one set of criteria and which by another (for example, high strategic or high dollar risk facilities may require sprinklers where high lif risk facilities may only require smoke detectors).

VI

CONCLUSIONS

The conclusions of this study program to develop a risk management methodology are:

1. The methodology is practical, usable and together with the special rules, applicable to all cases evaluated;
2. Once a familiarity with the system is gained, no significant increase in field survey time is required;
3. The methodology will provide reasonable consistency in analysis and presentation of fire risk data from NavFac office to office and from man to man;
4. The methodology will clearly indicate the level of risk which is being assumed. This information, in conjunction with population and fire loss data, will ultimately provide finer guidelines for the risks that should be assumed.
5. The system is adaptable to automatic data processing.

VII

RECOMMENDATIONS

As a result of the study program, the following recommendations are made:

1. Design and institute a training course for the application of the methodology for all field personnel;
2. Implement the field application of the methodology;
3. Provide 1) a description of the system, 2) an outline of the benefits which will accrue and 3) continued system output to Navy commands concerned with budgeting and funding fire protection improvements at shore facilities;
4. Take the necessary steps to begin accumulating data required to modify the tables and curves of the methodology to reflect Navy experience;
5. After a suitable period of time, conduct a detailed evaluation of the history generated following implementation and alter the methodology as required. Conduct periodic reevaluations of the data collected and the results obtained from the methodology and modify as required;
6. Investigate the feasibility of adapting the methodology to existing data processing capabilities.