RISK ASSESSMENT IN TELEPHONE EXCHANGES

by

Peter F.Johnson

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Peter F. Johnson

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APPROVED:

Robert W. Fitzgerald

Professor Robert W. Fitzgerald, Major Advisor

Craig Van Anne

Mr. Craig Van Anne, Associate Advisor
Hartford Steam Boiler Co., San Francisco, California

Vincent J. Hession

Mr. Vincent Hession, Associate Advisor
Bell Communications Research, Piscataway, New Jersey

David A. Lucht

Professor David A. Lucht, Director

ABSTRACT

The telephone network is the major focus for communication and data transmission in many countries. Telephone exchanges, as node points of the switching network, represent a major capital investment, and minimal property damage and interruption to the operation of these exchanges have been shown to be important objectives of any telephone company organization.

Within the context of an overall risk management program, the concepts of asset identification and determination of frequency and severity of loss due to a range of perils have been examined and related to telephone exchange operations.

A systematic framework has been developed to assess what it is that is at risk in any given telephone exchange. This critical areas procedure is designed to identify high risk areas, both in terms of potential property damage and business interruption. The procedure utilizes a functionally based approach that is pictorial in presentation and well suited to management decision making. It can be used to examine the risk from a number of different perils, although the emphasis in this research is given to fire.

The quantitative methods of hazard analysis, probabilistic risk assessment (PRA), and an Engineering Method for Building Firesafety have been shown to be logical extensions of the critical areas procedure developed. Illustrative examples using these three methods highlight possible quantitative approaches to risk assessment in telephone exchanges.

In order to support a more detailed quantification of risk , a range of fire incident data and loss statistics for telephone exchanges and computer facilities have been summarized. Typical loss scenarios and financial loss data are provided that illustrate the significant potential that exists for property damage and business interruption in telephone exchanges today.

PREFACE AND ACKNOWLEDGEMENTS

The telecommunications industry is undergoing a rapid transformation worldwide. The nature and extent of information passing through the network is changing as well as the equipment technology. In some cases, the corporate or government structure supporting the telephone network is undergoing reorganization.

These fundamental changes will inevitably alter the risk of property damage and operational interruption and may affect markedly the attendant financial liability of any telephone company should a major loss occur.

With this evolution of the telephone industry in mind, Professor Robert Fitzgerald issued a challenge to undertake the development of a systematic framework for the assessment of risk in telephone exchanges. I accepted the challenge and am deeply indebted to Prof. Fitzgerald, as my major thesis advisor, for his wisdom and guidance throughout the gestation period of this risk assessment approach. His considerable insight into the real problems of risk analysis and his friendly encouragement then enabled me to see this project through to an ultimate conclusion.

Also important to the development of this thesis was Mr. Craig Van Anne of Hartford Steam Boiler Inspection and Insurance Co., San Francisco. His strong background in risk analysis, combined with an extensive knowledge of the telephone and insurance industries, provided the basis for many important discussions at various review stages of the project.

Many others assisted greatly in the development of this research. The following warrant special mention:

- Mr. Vincent Hession, Bell Communications Research, for most valuable discussions on the Bell System practices for fire protection.
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- Professor G.E.Apostolakis of UCLA and Mr.H.K.Hasegawa of Lawrence Livermore National Laboratory for special information on quantitative methods of risk assessment

A most important contribution to this work was made by the Hartford Steam Boiler Inspection and Insurance Co. of Hartford, Connecticut. I wish to record my gratitude to Mr.Don Schubert (Manager, Property Engineering Department) as well as to Tom Barry, Pete Matthews, Don Drewey and Jim O'Brien for many important discussions, literature exchanges and arrangements made to visit and inspect a range of operating telephone exchanges. Worthy of particular note are Corporate Fire Protection Consultant Tom Barry, and members of the CAD Department at HSB, namely Steve Goeckler, Bruce Soucy and Don Tarr, for their professional preparation of all the thesis graphics.

Another group important to acknowledge is the faculty, staff and my fellow students at the Center for Firesafety Studies. The many thought provoking discussions and assistance with the thesis production were most appreciated.

On a personal note, special thanks are due to my Australian friend and mentor, Mr. Len Gibson, who sparked my initial interest in fire protection and has continued to guide my career. Mr Gibson, through his extensive knowledge of telecommunications and fire safety, amongst other things, has been a strong supporter of this thesis in many important ways.

Finally, I would like to thank my wife Judy and daughter Claire for their encouragement during all the times I was 'locked away at my desk' as well as for the emotional and digestive sustenance provided that allowed me to complete this major task.

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1. INTRODUCTION

The telephone network has become the focus for communications in most countries of the world. It now carries a range of important information besides telephone calls that includes :-

- computer data
- video transmissions
- telex, telegraphic/electronic mail
- fire, security and other alarms
- national defence information

The network is subject to many perils that can destroy equipment or interrupt services. For instance, one recent fire in a cable tunnel beneath a telephone exchange in Japan [1] shut down 89,000 subscriber circuits and paralyzed the nationwide on-line computer processing system of five major banks, taking 9 days to be fully restored. Fire and other perils such as flood, earthquake, electromagnetic interference and terrorism lead to a potential for loss that is uncertain. That is, there is a risk associated with the operation of a telephone system that the risk manager of a telephone organization would seek to minimize if profits or other corporate objectives are to be achieved.

At one level the risk manager of a telephone company must look at his overall network that may consist of some hundreds of telephone exchanges (central offices) as well as many other specialized buildings, and the interconnecting communication links. Corporate goals, policies and standards must be appropriately derived for the overall organization - see Crowley [2].

At another level the risk manager must address the risk of a major loss at any particular telephone exchange and the impact of that locally and on the overall network. Appropriate loss control measures for individual exchanges must also be derived.

It is the localized risk assessment of a central telephone exchange, rather than the corporate overview, that this research addresses. At present, there seems to be no overall framework by which an engineering consultant or telephone risk manager can examine logically the potential for loss of property or interruption to business in a telephone exchange in any quantitative manner.

This research is designed to provide such a framework, based on a functional understanding of a telephone exchange, that can assist in the identification of:

- what is at risk
- what is the potential for loss.

The procedural framework could be used to examine the risk of loss in a telephone exchange for any peril, although the emphasis in this thesis will be given to fire.

2. BACKGROUND TO RESEARCH

The assessment of what is exposed and what is the potential for loss in major telephone exchanges is of interest currently for a number of reasons:

(i) Telephone exchanges represent a tremendous property investment. The profile of one U.S. company reads as follows:-

- 190 major locations, most over $10 million
- 30% of exchanges over $25 million
- some exchanges over $250 million.

(ii) Telephone systems are undergoing tremendous technological changes with the introduction of compact, digital electronic equipment and new technologies such as satellites, fibre-optics and artificial intelligence systems.

(iii) There are major corporate changes in the U.S. telephone industry with the divestiture of the AT&T/Bell group and the growth of long distance telephone competitors. In the U.K., the former government owned British Telecom is now a private company.

(iv) The divestiture and privatization of telephone companies introduces the need for private insurance. Previously, huge corporations or government telephone organizations could absorb substantial losses and were either non-insured or carried limited catastrophic coverage only. Now much greater involvement of insurance companies encourages investigation of risk assessment procedures.

(v) Risk management is being used increasingly as a corporate tool for maximization of profits. The quantitative methods of risk assessment are being sought as bases for risk management decisions.

(vi) Telephone companies are generating very high revenues, some centers billing $20 million per day. Consequently, there are concerns about business interruption losses and damage or loss of revenue/billing data, records and equipment.

(vii) There is a growing propensity for businesses that are heavily dependent on telephone services to sue for damages in the event of a loss of those services.

(viii) There are moves in some telephone companies to a centralization of billing and information processing and an industry-wide push towards automation and reduction in manning levels in telephone exchanges.

(ix) There is concern for the growth of new hazards such as

- arson
- terrorism
- electromagnetic pulse (EMP) from nuclear explosions
- radio interference.

All of the above aspects will have a major impact on future losses in telephone exchanges and on the business consequences of those losses that are somewhat different to the record of exchanges in the past.

3. TELEPHONE EXCHANGE OPERATIONS

A telephone exchange performs what is essentially a simple operation. It takes an incoming call, identifies the party sought, finds the most efficient route, tests the line for availability and continuity and then connects the two parties. The complexity comes in engineering a system that is stable, reliable, maintainable, serves a large number of subscribers, uses the minimum amount of equipment and maximizes efficiency.

In addition to switching telephone calls, telephone exchanges typically provide special circuits for data transmission, and dedicated leased lines for alarms, video networking and emergency services use. As well, they may house operator assistance personnel, information centers, testing/maintenance facilities and administrative offices.

The local area (end) offices usually have a large number of cable pairs entering from local subscribers. In contrast, the tandem or toll offices, which connect local offices and transmit long distance, carry digitally coded, multiplexed signals over coaxial or fiber-optic cables and via microwave or satellite links.

The services equipment in exchanges is critical to the proper and continuing operation of the telephone equipment. It includes:

- HVAC, steam, chilled water
- power, mains 50 VDC
- emergency power, turbines, diesel generators
- fire alarm, security systems.

Similarly, the proper maintenance of the telephone equipment itself and the avoidance of equipment losses are important because :

- some local services have no redundancy
- some major exchanges are critical to the efficient switching of the overall network
- loss of some transmission equipment requires replacement of matching, undamaged equipment in other exchanges of the network
- some equipment has a manufacturing lead time of up to 6 months.

More details on telephone exchanges, their operations and buildings, the latest switching equipment and their fire protection in the U.S. may be obtained fron the following references:-

Pferd. A Century of Telephone Buildings. [3]

R.F.Rey (ed.) Engineering and Operations of the Bell System. [4]

B. Briley. Telephone Switching. [5]

W.S.Hayward (ed.) The 5ESS Switching System. [6]

FM Loss Prevention Data Sheet - Telephone Exchanges. [7]

4. RISK MANAGEMENT AND RISK ASSESSMENT TECHNIQUES

4.1 Introduction

As in other industries, a telephone company risk manager would like to be able to identify the extent of his company's exposures to fire, flood, explosion etc.. Ideally he would like to have a precise, predictive method by which he could state that, based on 99% confidence limits, a fire causing $2 million maximum should occur no more than once every 50 years in a specific telephone exchange.

The risk of loss at one specific location and from one peril, however, should not be examined in isolation. The individual risks need to be evaluated within the context of an overall company risk management plan and in terms of the corporate objectives of that plan.

4.2 Risk Management

Church [8] and Van Anne [9] give details of an overall risk management plan could be applied to an overall corporate structure or to a single location like a telephone exchange. It has 6 basic steps. They are :-

(i) identification of assets and exposures
(ii) estimation of frequency and severity of loss
(iii) examination of loss control and risk financing alternatives
(iv) selection of appropriate alternatives
(v) implementation of one alternative
(vi) monitoring and readjustment of the program.

Risk assessment or risk analysis procedures are the engineering tools that address steps (i) and (ii) of the risk management process. These tools provide the risk manager with a characterization of the existing level of risk and risk assessment methods will form the major focus of this project.

Step (iii) of the risk management plan is concerned with the balance between loss control and risk financing and the choice of an appropriate course of action to deal with the given exposure. For this decision, the risk manager requires more information than simple loss frequency and severity figures. One vital piece of information required is the objective or level of performance that it is desired to maintain. Only then can a proper decision be made as to whether to:

(a) assume the risk
(b) transfer the risk (insurance)
(c) reduce the risk (loss control - protection).

For example, a telephone exchange serving a number of major on-line data processing bank operations may not be able to afford to have its switching fall below 90% of capacity (the objective). In this case, a halon system might be considered in order to reduce the risk of serious interruption to services by fire. Alternatively, business interruption insurance might be sought to offset any loss of revenue should a fire occur. In contrast, for another exchange serving a declining market and having a peak demand of only 30% of total capacity, the risk of serious interruption to services may be so small that no action is taken and the risk is assumed.

Before looking in detail at risk assessment methods, it would be useful to briefly examine the risk management objectives that might be appropriate to a telephone company.

4.3 Risk Management Objectives

Williams and Heins [10] suggest that a corporation could have eight possible objectives for their risk management plan. They are:

- corporate survival
- management peace of mind
- higher profits
- fairly stable earnings
- little or no interruption to operations
- continued growth
- good corporate image
- satisfaction of external obligations.

These risk management objectives are said to be a function of:

- corporate goals
- corporate business environment
- peculiar corporate or organizational attributes.

For telephone companies in the US, the recent divestiture of the Bell System and increasing competition between long distance telephone companies has certainly changed the business environment. As a result of the highly competitive environment, some US companies may be currently emphasizing corporate survival and stable earnings as objectives and thinking less about higher profits and continued growth at this time.

For individual telephone exchanges, the corporate objectives for risk management are usually re-expressed in terms of:

- life safety
- property damage (P.D.)
- business interruption (B.I.)

There may, however, be other local objectives such as revenue loss expectations, goodwill considerations and maintainance of a particular community image.

DeCapua and Simpson [11] suggest that, since telephone exchanges are low occupancy, secured, controlled environments, the life safety objective is not the controlling factor for risk assessment. For example, no lives have ever been lost in US telephone exchanges due to fire. Thus, this project will address only the two latter objectives of property damage and business interruption that dominate exchange design and construction practices and potential losses.

For property damage, the objective set for any particular exchange would depend upon the company's approach to factors such as:

- risk retention and aversion to risk
- risk financing policy
- property damage insurance availability
- loss control measures in place and planned.

For example, a company might choose a local exchange P.D. objective of $1 million per annum within an overall corporate loss objective of $5 million maximum per annum. This might be based on an acceptable loss/investment ratio and statistical data of previous network losses.

Business interruption losses for telephone exchanges could result from failure to maintain the switching network as well as loss of revenue due to failure or damage to billing equipment. The loss of up to $50 million by one US telephone company due to a computer error [12] is an interesting recent example of this latter type of failure.

The business interuption (B.I.) objective might best be expressed in loss of revenue terms. However, no telephone company is known to have such a method established. Instead, B.I. objectives are usually related to frequency, extent or duration of interruption. Typical types of limits are:

- maximum number of lines affected
- maximum period of interruption to service.

As an example, DeCapua et al. [11] state that the Bell System had a maximum total interruption of 3 days as their objective for any exchange. Given the growing dependence of all forms of communications on the telephone network, much shorter periods of total interruption may be necessary objectives.

With objectives for both property damage and business interruption established, risk assessment methods can now be examined that might be appropriate to telephone exchanges.

4.4 Literature Review of Risk Assessment Techniques

A review of the literature shows a wide range of techniques that are loosely described as risk assessment or risk analysis methods. They include techniques such as :

- Delphi studies
- NFPA Firesafety Concepts Tree
- Mond, Dow index
- success/fault tree analysis
- event tree analysis
- failure mode and effects analysis
- diagraph methodology
- probabilistic risk analysis
- HAZOP Studies
- Engineering Method for Building Firesafety

A number of sources , such as Lees [13], list the advantages and disadvantages of the various techniques, no reference was found that showed which methods were merely parts of other more extensive analyses and which were complete risk assessment approaches by themselves. An examination of all available techniques was undertaken. This examination suggested that the general risk assessment methods are best divided into two categories as follows:

(i) those providing a rating that allows different plants or parts of a facility to be ranked in terms of potential loss. e.g. Delphi studies, Dow Index, Mond Index

(ii) those providing a quantitative probability of loss in a particular plant or facility
e.g. Probabilistic risk assessment (PRA)
Fitzgerald firesafety evaluation method

Figure 1 provides an outline for quantitative risk assessment and shows how it provides information for the risk management process. The general order of analysis, based on work by Tuler [14], is detailed. The respective stages of analysis at which the different risk techniques, such as HAZOP studies and fault trees, are used, are also shown.

For fire protection in telephone exchanges, it appears that no quantitative engineering risk assessment procedures are used at this stage. Therefore, risk managers must rely on subjective judgements of the risk from fire. Some qualitative methods are employed. For example, one company uses a modified NFPA Firesafety Concepts Tree as a basis for its engineering standards on fire protection [11].

FLOW DIAGRAM OF RISK ANALYSIS

REF:TULER

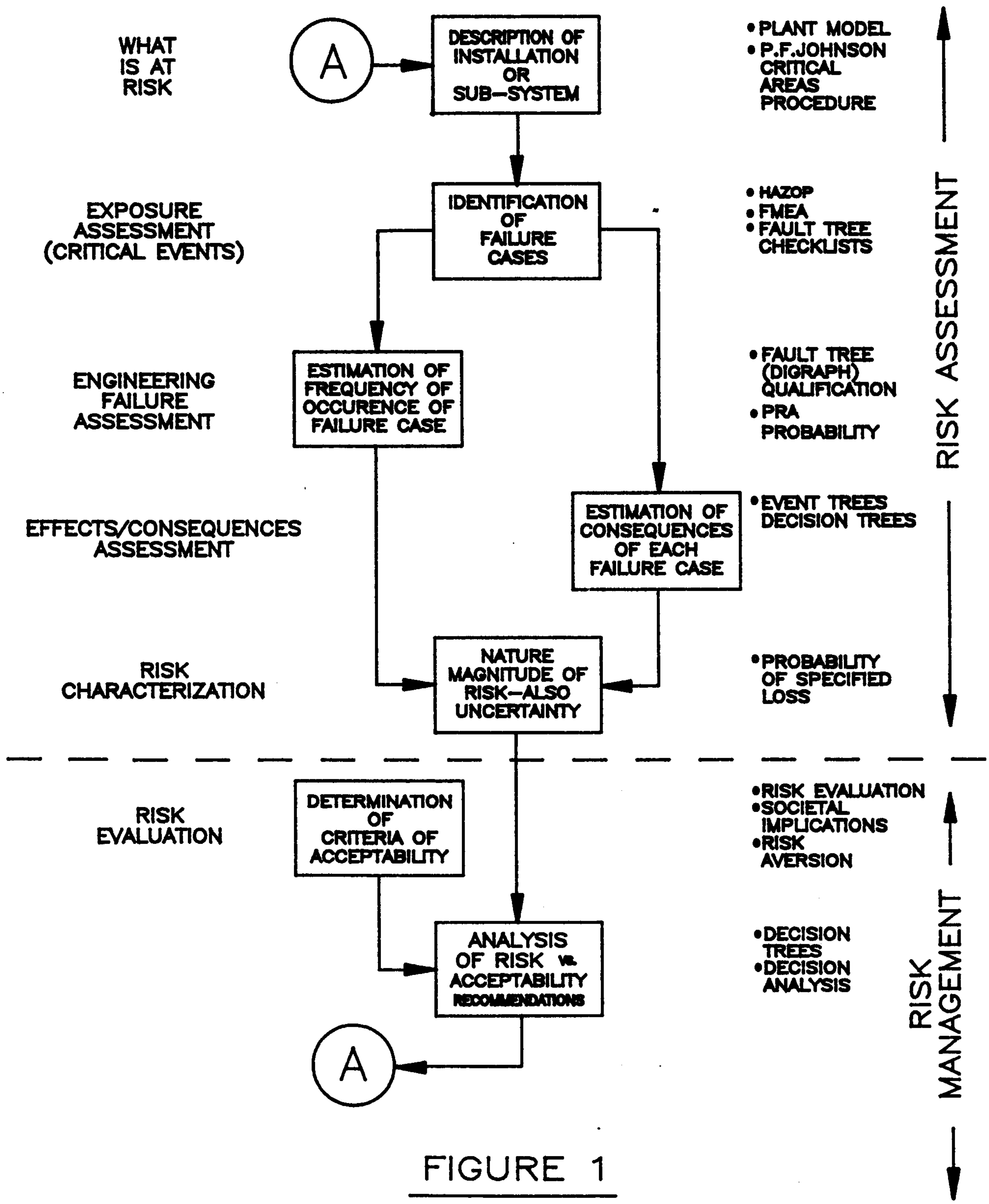


FIGURE 1

4.5 Assets and Exposures

Figure 1 shows that before risk assessment techniques can be applied to the investigation of any system, such as a telephone exchange, the actual assets involved (i.e. what is at risk), and the perils to which that facility will be exposed, first need to be determined.

Head [15] suggests that for any exposure there are a wide range of perils that impact on 4 basic categories of assets in any given location. The 4 categories of asset that are at risk are :

- property
- net income
- liability
- personnel.

This research project is directed towards property losses and the business interruption aspects of net income that might benefit from an engineering approach. As well, only the physical exposures of fire, flood, earthquake, explosion etc. are considered. Other aspects of employee dishonesty and political risks as well as issues of liability and loss of key personnel are generally not addressed, although the liability issue arising from business interruption and failure to provide a telephone service may be incorporated into the considerations addressed by this study.

Discussions with telephone company representatives, a review of the literature, and examination of consultant reports suggest that the evaluations of telephone exchanges, from a property and business interruption loss viewpoint, are not being done on any systematic basis. Also, all areas of an exchange appear to be treated equally, and simply examined for compliance with building codes or company standards.

The central focus of this project is, therefore, directed towards a systematic approach of identification of 'what is at risk' in a telephone exchange. In order to make it most useful to an engineering consultant reviewing a particular exchange location, it was felt that the approach should be:

- straightforward to use
- easily understood by telephone company upper management
- functionally based
- pictorial in presentation
- suited to evaluation of both property damage and business interruption
- adaptable to both simple and more sophisticated risk assessment methods.

5. CRITICAL AREAS PROCEDURE

5.1 Rationale for the Procedure

Kazarians et al. [16] in a general methodology for fire risk assessment of nuclear power plants suggests that the first step in risk assessment is to identify what is at risk, through a plant model, and examine the possible failure scenarios.

For telephone exchanges, a reasonable approach would seem to incorporate the conceptual idea of Kazarians et al to determine critical areas of an exchange. They define a critical area as a "fire area, defined by rated fire barriers, which contains equipment whose fire-induced failure can lead to an initiating event." In nuclear plants the end result of an initiating event could be a loss of coolant accident (LOCA) or core meltdown. Thus, the frequency of "initiating events" is the aim of the probabilistic risk analysis.

For telephone exchanges, both frequency of loss as well as severity of property damage and business interruption are important. In addition, it seems desirable to have a general basis for assessment of risk that could be used to address other perils as well as fire. Therefore the definition of "critical area" has been changed somewhat to mean "a defined area of equipment, whether separated by fire barriers or not, whose failure could lead to a defined reduction in operations of a telephone exchange".

The basic approach of this procedure requires the consultant to construct both functional and physical arrangements of an exchange in a series of schematics, plans and sectional views. Then, a survey form is provided for the consultant to identify, with the assistance of the telephone company, those critical areas of the exchange where fire or other peril could create property damage or business interruption losses in excess of identified acceptable limits (objectives). These critical areas are then highlighted on the schematics and physical drawings so the consultant may:

- identify concentrations of high value equipment
- locate areas containing redundant equipment that might be subjected to 'common mode failure'
- focus on compartments or equipment areas worthy of more detailed risk assessment studies
- identify telephone operations that exhibit dependence upon critical services equipment.

The procedure for identifying these critical areas is contained in Appendix A. It is written in a detailed step by step format so that a consultant wishing to use the procedure, but unfamiliar with it, should be able to complete it without difficulty. It consists of five (5) major sections :

(i) telephone equipment schematic

(ii) services equipment schematic

(iii) floor plans and sectional views

(iv) critical areas - property damage

(v) critical areas - business interruption.

While full details of the 5 sections are provided in Appendix A, each section will now be briefly introduced.

5.2 Telephone Exchange Schematic

The first step in the procedure is to construct a schematic of the telephone equipment using general blocks typically found in telephone exchanges, such as:

- cable entrance facility (CEF)
- multiplexing equipment
- distribution frames (MDF)
- switching equipment
- controlling computer
- records/billing equipment.

This requires the consultant to visit the particular site under consideration and gather specific information. Some telephone exchanges do have limited functional schematics of their operations that can be useful. Regardless of the availability of these schematics, the job is best approached by starting where the telephone cables come into the exchange (CEF), and following them through to the switching equipment and any centralized computer and billing equipment.

This schematic is based on the 'mission reliability' modelling concept used in military standards [17]. Functional blocks are joined in SERIES for dependent equipment and joined in PARALLEL for equipment that is redundant, in order to illustrate the functional relationships between the different sections of equipment. An example is shown in Figure 2.

Also shown on this schematic are services inputs to these telephone equipment areas. These services are extremely important. The loss of cooling airflow, for example, in modern digital switching equipment can quickly lead to localized heating which may, in turn, result in equipment damage or operational shutdown. These inputs are colour coded for later identification on the services equipment (HVAC etc) schematic.

Finally, provision is made for identifying and marking in details of the physical barriers, such as walls and floor/ceiling assemblies, on this functional schematic. For simplicity, Appendix A describes four types of barriers of increasing strength to be used. Each type has an identifying symbol (e.g. SB, OB) and these should be used to label barriers on the schematic between functional blocks as illustrated in Figure 2. This labelling of barriers is not always possible where the physical layout of equipment does not follow the functional arrangement. However, where the physical layout does coincide with the functional arrangement, this identification od barriers tends to give a clearer idea of critical areas. In particular, those areas which Kazarian et al. [16] see as most important are highlighted. That is, the ones in which several redundant components or systems are located within the same compartment.

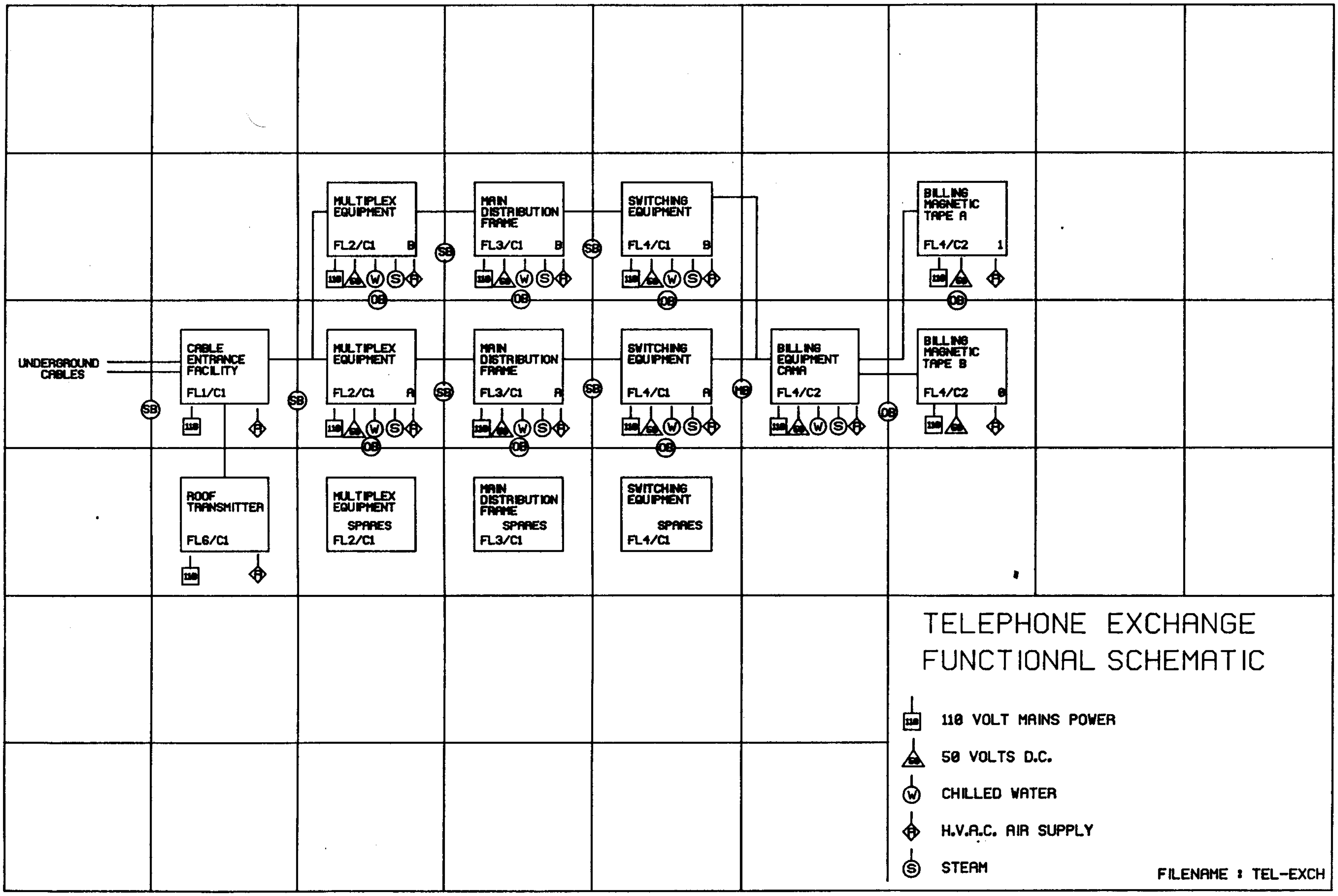


FIGURE 2-TELEPHONE EQUIPMENT

5.3 Services Equipment Schematic

Telephone equipment requires an uninterrupted supply of 50 V DC power and also is highly dependent upon the maintenance of controlled environmental conditions. This applies particularly to the new digital switching and computer equipment. Thus, equally as important as the telephone equipment for exchange operations are the building services of:

- mains power
- HVAC (fan rooms)
- chilled water
- steam (in some cases)
- standby power.

Consequently, a services equipment schematic must be constructed. Figure 3 shows a typical schematic. Again, dependent and redundant equipment should be shown in SERIES and PARALLEL respectively and colour coded as before. The same ratings on physical barriers, where possible, also should be used. In some cases where, for example, 2 redundant chillers are in one physical compartment, the barrier between them is of "zero strength" and should be marked OB in accordance with Appendix A.

Relatively simple functional schematics of services equipment are not generally available for exchanges. They are quite simple to construct, however, and are best done by starting in

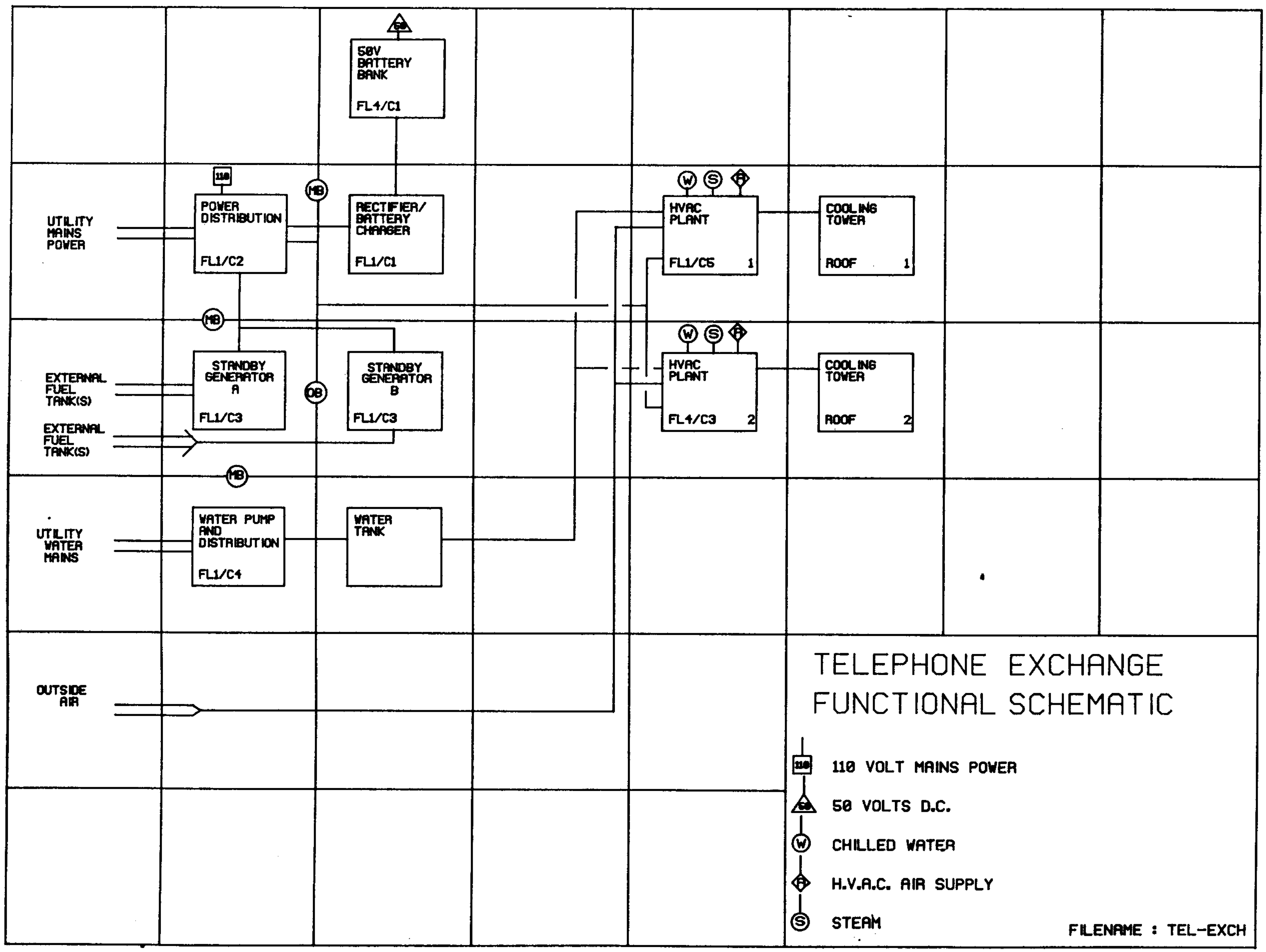


FIGURE 3-SERVICES EQUIPMENT

a telephone equipment area and working backwards to an external or utility input. With regard to electric power, for example, one can trace back through the battery room, rectifier equipment, mains power distribution area, mains transformer and incoming utility power main. A sub-system would be the standby power generator(s) and their fuel systems.

5.4 Floor Plans and Sectional Views

The functional telephone and services equipment schematics serve as a framework for identification of assets in an exchange and, hence, as a basis for assessing the risk of property damage. However, in a telephone exchange, as in a nuclear plant, there are a number of critical areas where several redundant components or systems are close together. These often occur in cable chases, shafts, ducts etc. If these are lost, they may represent little in terms of property damage but could have disastrous effects on overall exchange operations.

The third step in the Appendix A procedure, therefore, is to construct floor plans for each storey of the building, together with sectional views to clearly illustrate the physical relationship between the various sections of equipment, and the vital interconnections (see Figure 4). This is probably the most time consuming part of the procedure, and the telephone company may not have useful drawings that could assist in this task. If drawings do exist, they may not be up to date as most

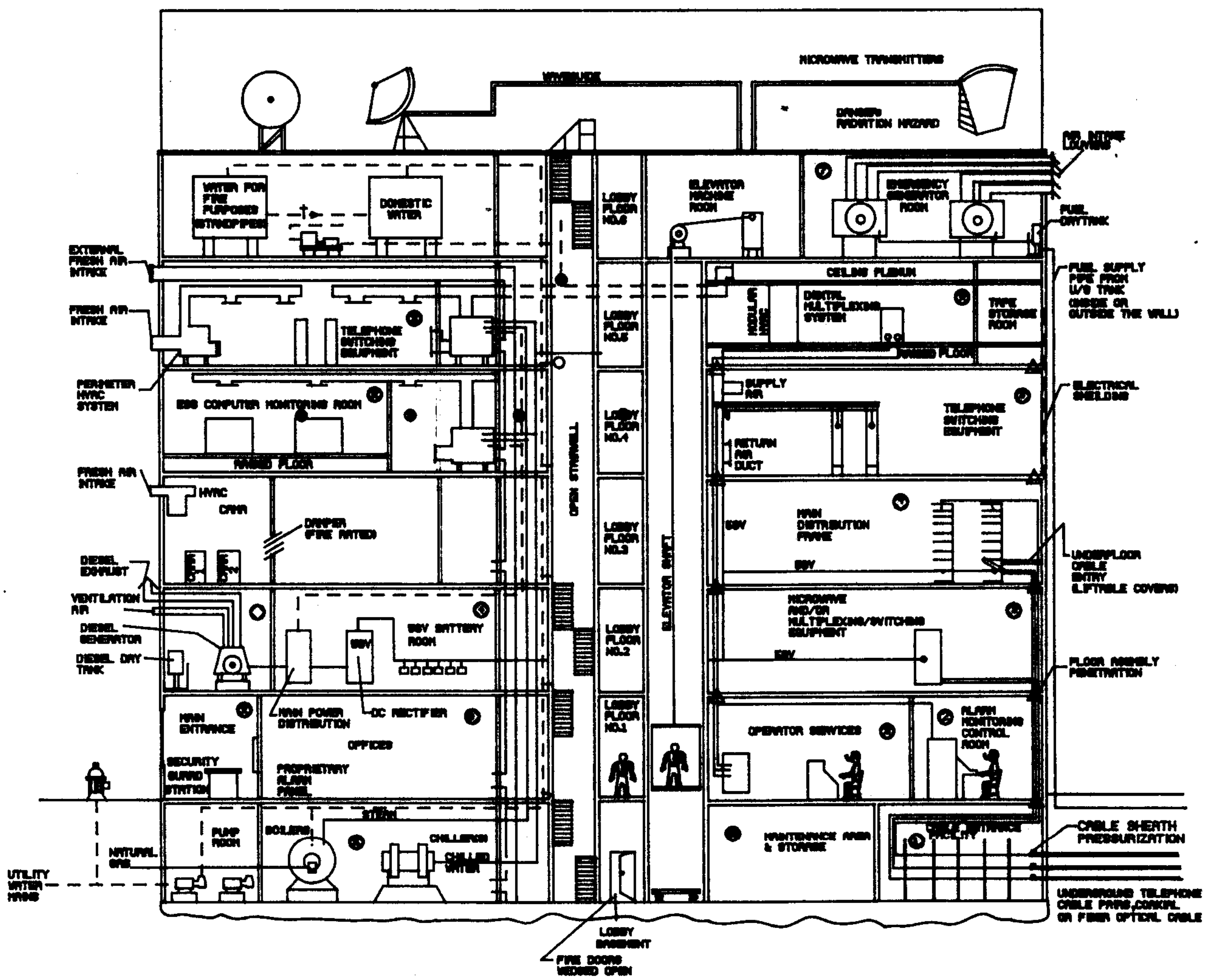


FIGURE 4-SECTIONAL VIEW OF TELEPHONE EXCHANGE

exchanges are in a constant state of modification due to the introduction of the new digital equipment technology. A consultant or design engineer using this procedure would have to make a decision as to the scope and complexity of drawings that achievable within the time frame and budget for the project.

5.5 Critical Areas - Property Damage

In order to systematically determine the extent of potential property damage in a central telephone exchange and to identify vital sections of equipment that would be costly to replace, the procedure in Section 4 calls for the setting of a property damage (P.D.) objective and the completion of a survey of equipment replacement costs.

As dicussed in Section 4.3, the P.D. objective would typically be a dollar limit on a single loss incident or annual total loss basis. It may be related to insurance coverage held or to a corporate loss/investment ratio.

The survey to be completed is part of the critical areas procedure and a sample survey form is included in Appendix A. It is based upon the functional schematics developed for the particular telephone exchange, and requires the replacement costs of equipment to be identified as well as supply and replacement times and other information related to business interruption. The form could be modified to include normal loss expectancy (NLE), maximum foreseeable loss (MFL) and amount subject, terms clearly defined by Van Anne [9].

Once the survey form is completed, all areas of equipment having a replacement cost greater than the stated P.D. objective could be displayed in colour/hatching etc. on the schematics (and the floor plans and sectional views). This provides the consultant with a clear pictorial method for presenting concentrations of high value equipment to the telephone or insurance company client (see Figure 5).

5.6 Critical Areas - Business Interruption

Fires such as those in Japan [1] and New York [18] show that the result of a loss incident can have a far greater impact on telephone company revenue and interruption to customer business than just property damage. This business interruption susceptibility has become even more critical because of the enormous spread of business information systems and computer data links for banks and other institutions that utilize the telephone network extensively.

The procedure, described in Appendix A, provides a method for establishing both telephone and services equipment areas critical to meeting a particular business interruption (B.I.)

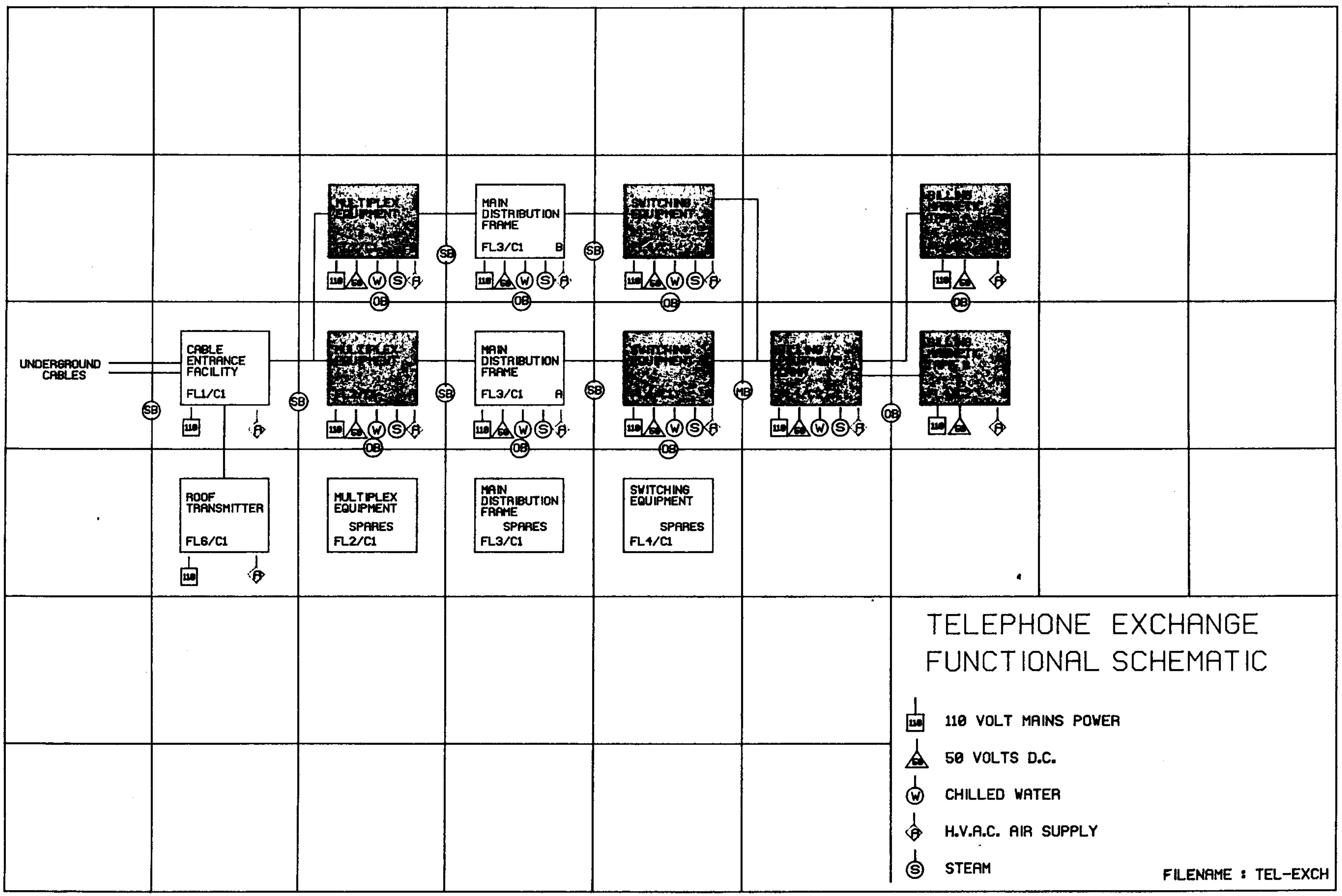


FIGURE 5-EQUIPMENT IN EXCESS OF P.D. OBJECTIVE

objective. Again, this B.I. objective is a decision for the telephone company risk manager who may set limits for losses in terms of :

- maximum number of telephone lines
- maximum time interruption to service
- maximum loss of revenue

or some combination of these.

With the B.I. objective established, the completed survey form mentioned in the previous section (see Appendix A) should be used to determine the equipment areas which are critical to the B.I. objective and which must remain operational if this loss objective is not to be exceeded. These critical areas can then be coloured/hatched on the schematics. The highlighted areas will provide the client with a pictorial presentation of business interruption potential - see Figure 6 .

The simple use of schematics, however, for business interruption will not highlight telephone cables and services interconnections in common ducts, cableways, shafts etc. Here, a small, seemingly insignificant loss could, perhaps, lead to a major B.I. loss. Therefore for B.I., the process of critical area identification must be extended to include these critical locations, and they should be highlighted on the floorplans and/or sectional views.

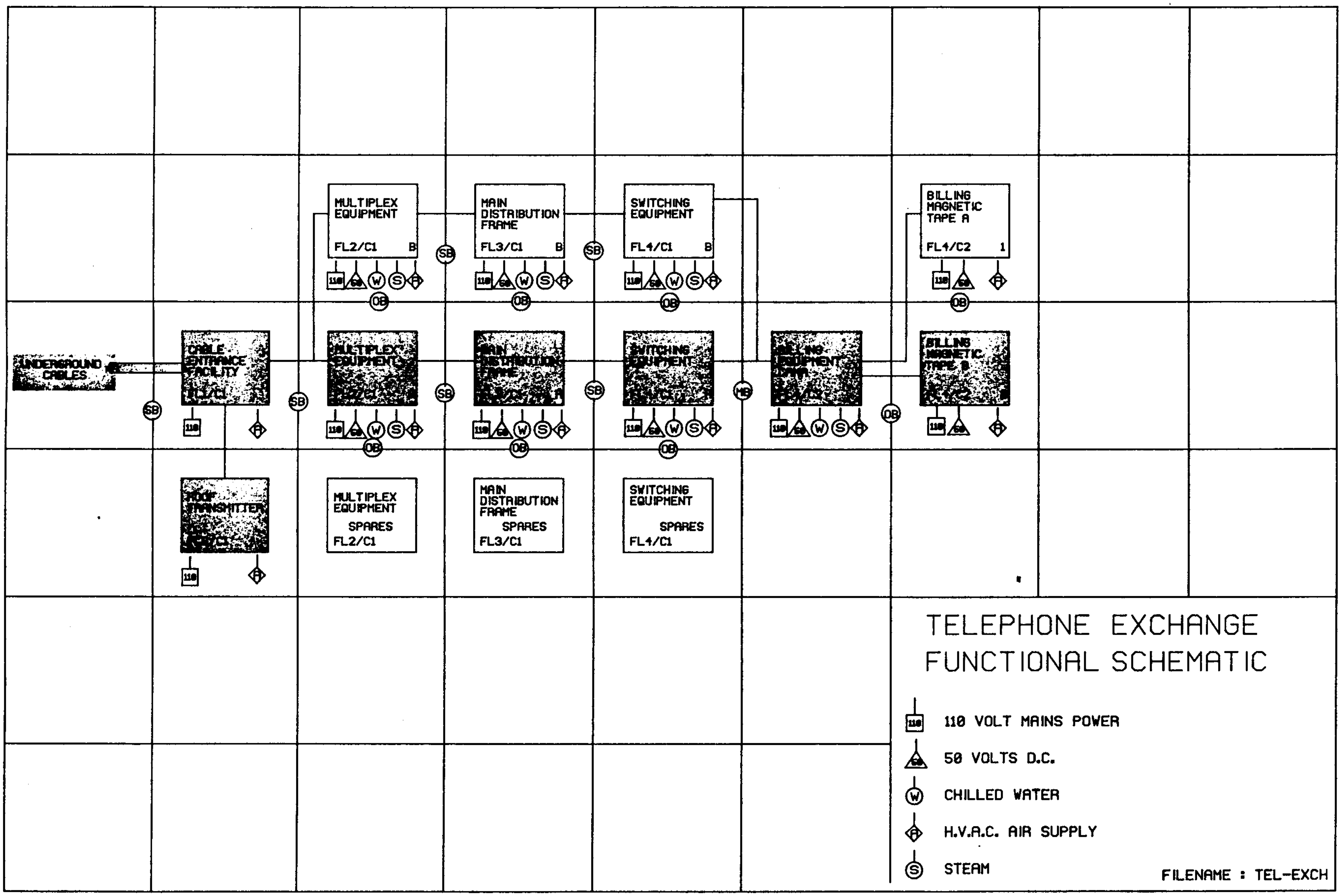


FIGURE 6-EQUIPMENT AREAS CRITICAL TO B.I. OBJECTIVE

5.7 Procedure Presentation

The critical areas procedure serves as a framework for a consultant to identify the vital elements of an exchange in terms of property damage and business interruption. The important areas would be highlighted for the client in a pictorial manner via the schematics and other drawings. They would also be documented in the survey form designed for the purpose as part of the procedure.

Once the critical areas are identified, the next step for a consultant would be to determine and discuss the frequency and extent of potential loss and the design alternatives that might mitigate that loss. In the case of fire, this might consist of an analysis, using the Fitzgerald Engineering Method for Building Firesafety for example. This could be extended to include a discussion of design alternatives and probabilities of loss through decision analysis, such as that proposed by Van Anne [9].

As an alternative to quantitative risk assessment, the critical areas procedure could simply be used by the consultant as a basis for qualitative discussion of relevant risk issues. For a telephone exchange, these issues might include operational redundancy, the effects of the new digital switching technology, and exchanges in shared tenanted facilities.

Chapter 6 of this thesis is devoted to a qualitative discussion of some contemporary loss control issues in telephone exchanges. Chapter 8 examines a number of more detailed quantitative risk assessment methods that naturally follow on from the critical areas procedure.

To give an indication of how a consultant might use the critical areas procedure, a summary presentation for a hypothetical telephone exchange is illustrated below.

****

SUMMARY REPORT

TELEPHONE EXCHANGE - RISK ASSESSMENT

****

Company	:	XYZ Telephone Company
Location	:	200 Main Street, Newtown, MA, 00001.
Type of Facility	:	Local subscriber C.O. Serves local resident and business community
No. exchange lines	:	25,000
Floor area of facility	:	60,000 sq.ft.
No. floors	:	3
Property Damage (P.D.) Objective	:	$1,000,000 (total annual loss)
Business Interruption (B.I.) Objective	:	1000 lines for 1 day or $1,000,000 loss revenue (whichever is less)

****

****

Drawings provided:

1. Telephone equipment schematic
2. Services equipment schematic
3. Floor plans (3 floors)
4. Sectional views (x2)
5. Telephone equipment (P.D. objective)
6. Services equipment (P.D. objective)
7. Telephone equipment (B.I. objective)
8. Services equipment (B.I. objective)

Survey form documents replacement cost, supply/repair time, and installation time for all identified telephone and services equipment areas.

Total value of structure and contents : $45,000,000.

****

Comments:

The drawings nos. 5 - 8 show that 3 areas are critical to the operation of the telephone exchange if the P.D. and B.I. objectives are not to be exceeded. These areas are :-

1. Cable vault - B.I. objective exceeded
2. Switch equipment (floor 1) - P.D. and B.I. exceeded
3. Billing Computer (floor 3) - P.D. and B.I. exceeded.

****

RECOMMENDATION

A. A detailed flood risk analysis should be undertaken for the cable vault in the building basement.

B. A more detailed risk assessment for fire should be undertaken using the Fitzgerald Engineering Method for Building Firesafety with particular emphasis on the 3 areas exceeding the P.D.-and/or B.I. objectives.

****

****

Once it is known 'what is at risk', the consultant can proceed to examine the expected frequency and severity of loss through some qualitative process or through a more comprehensive risk assessment procedure.

6. QUALITATIVE USE OF CRITICAL AREAS PROCEDURE

6.1 General

The critical areas procedure of Appendix A provides for the systematic identification of assets and their value in a telephone exchange together with a functional understanding of exchange operations that allows an examination of the potential for business interruption. The procedure would be more useful if one was able to proceed to the next step of establishing quantitative levels of risk, due to perils such as fire and flood.

However, before proceeding with methods that are more precise, but more time consuming, and, therefore, more costly to a consultant and his client, it is worth examining what can be learned qualitatively about telephone exchanges from the procedure. As Fitzgerald [19] suggests, the discipline of carrying out the procedure may be as valuable as the results it yields.

Kazarian et al. [16] suggest that a method of risk assessment based on a plant survey and engineering judgement "usually identifies all critical areas, although it is clearly not guaranteed to do so". However, such a method may provide a measure of risk, particularly on a comparative basis. In addition, it may highlight certain situations or physical arrangements obviously less conducive to safety or continuity of operations than others.

The critical areas procedure, developed here, has proved to be useful in highlighting a number of risk issues, particularly those related to fire.

6.2 Common Basis for Discussion

The functional schematics provide a useful means for discussion of equipment, building and safety design in a telephone exchange hitherto not available. The procedure highlights the relationships between the exchange's physical construction and the functional equipment within it. This should provide a common basis for discussion between telephone equipment designers, building engineers, operations people, risk managers, accounting/revenue personnel, safety engineers and insurance companies.

6.3 Comparative P.D./B.I. Ratios

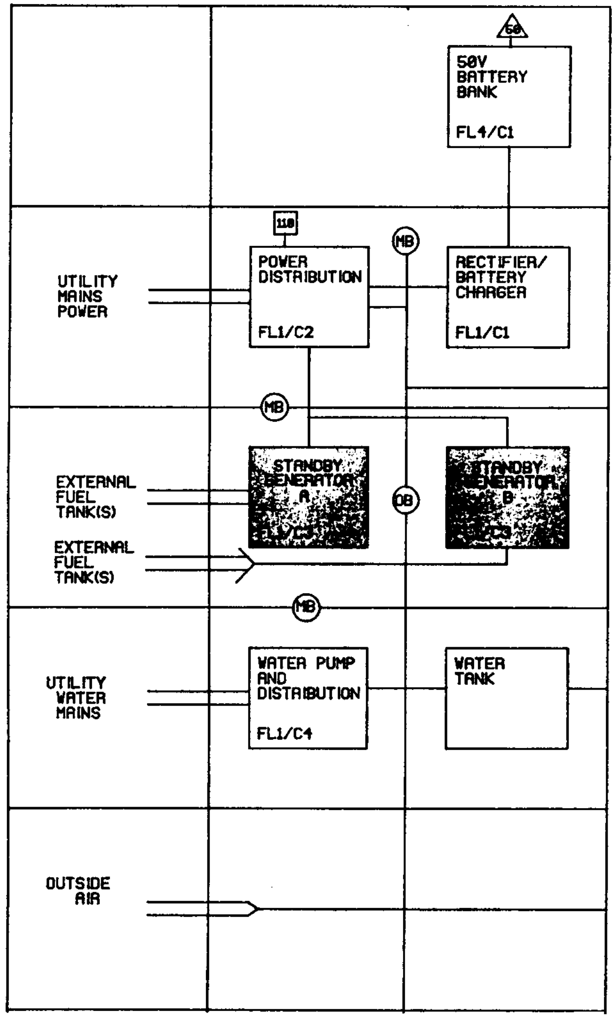
The schematics can also be used to demonstrate that a section of an exchange, be it telephone or services equipment, may have quite a different value depending upon whether it is examined from a property damage or business interruption point of view. Figures 5 and 6 show the contrasting situation for a cable entrance facility (CEF). This is usually a bare concrete lined vault or room, often subgrade, having a low combustible content except for the cable bundles. In toll centers particularly, the number of cables, often of a coaxial or fibre optic type, is very small. If penetrations are properly sealed, this area represents a low value asset that is not critical from a property damage standpoint. However most, if not all, incoming and outgoing signals pass through these cables in the vault. If the cables are destroyed, as in the Japanese fire [1] recently, the whole exchange operation can be effectively shut down , with enormous consequences for telephone company revenue and loss of business to subscribers.

A similar situation exists with the rectifier/battery charger and the 48 volt battery bank in the exchange. All telephone equipment is operated from these batteries in order that:-

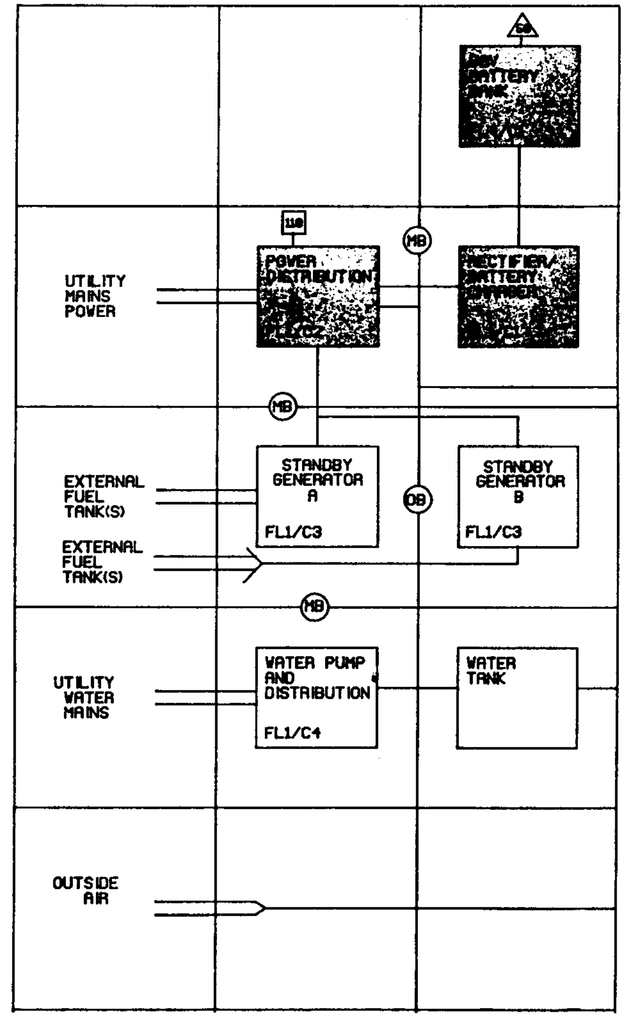
- telephone equipment is supplied with 'clean' DC power - the batteries tend to absorb voltage fluctuations or 'spikes' entering from the mains
- standby battery capacity is available should mains power be lost.

Thus, this equipment is absolutely essential to the continued operation of the exchange, even though it may not represent such a high value in terms of potential property damage.

The opposite situation is true for standby power generators. They may be very large in some exchanges, and may have high replacement value. However, they usually constitute a low potential for business interruption since they are only essential to exchange operations in the event of mains power outages (see Figure 7).



EQUIPMENT VALUE ABOVE
PROPERTY DAMAGE OBJECTIVE



EQUIPMENT VALUE ABOVE
BUSINESS INTERRUPTION OBJECTIVE

FIGURE 7-COMPARATIVE PROPERTY DAMAGE
& BUSINESS INTERRUPTION RISKS

What these examples highlight is that the result of a loss of a equipment may be quite different in P.D. or B.I. terms. It suggests that it would be advantageous to examine the operation of each section of equipment and its protection against fire, flood etc. from a functional rather than a strict code point of view. For example, the loss of a major HVAC fan unit could quickly cause an exchange shutdown due to overheating that has far more important implications than say, a similar HVAC fan failure in a hotel. The fire protection requirements, therefore, may need to be quite different in the two situations.

6.4 <u>Operational vs Peril Redundancy</u>.

The redundancy in telephone exchange equipment is designed from an operational viewpoint. Redundant switching equipment, for example, is installed on the basis that

- equipment has to be taken out of service for maintenance from time to time.
- redundant switching equipment could still carry a partial load in the event of a major loss of switching equipment
- for short times, almost all equipment is required to meet peak switching loads, but generally, considerable excess switching capacity exists.

What the procedure clearly shows in a number of exchanges is that while operational redundancy exists, redundant equipment is often installed in the same compartment and, therefore, is subject to the same common mode failure. Redundancy does not exist from the loss or hazard point of view. This is illustrated in Figure 8 where a fire in compartment FL4/C3 potentially could destroy both sets of switching equipment. Flame spread from one set of equipment to the other would not need to occur as the spread of smoke and corrosive gases would be enough to seriously impair the second set of equipment.

The second issue this raises is that telephone exchange buildings have consisted traditionally of heavy, reinforced concrete construction. They usually have very substantial floor/ceiling assemblies. This gives strong horizontal separation so that fire on one floor has difficulty penetrating to the floors above. However, from the point of view of fire seriously interrupting business, Figure 9 shows that the relationship between compartment barriers and redundant equipment is not correct. If, for example, one main distribution frame is lost, then the equipment that it serves on other floors is out of service as well - the strong separation provides no operational benefit. In contrast, if the strong compartmentation was designed to separate all parts of redundant systems (Figure 10), then when one set of equipment is lost, the other should survive intact.

The third issue highlighted relates to those critical areas of an exchange where there is no clear separation of redundant equipment. This occurs most particularly in the cable vault. For end offices (i.e. exchanges serving local subscribers),

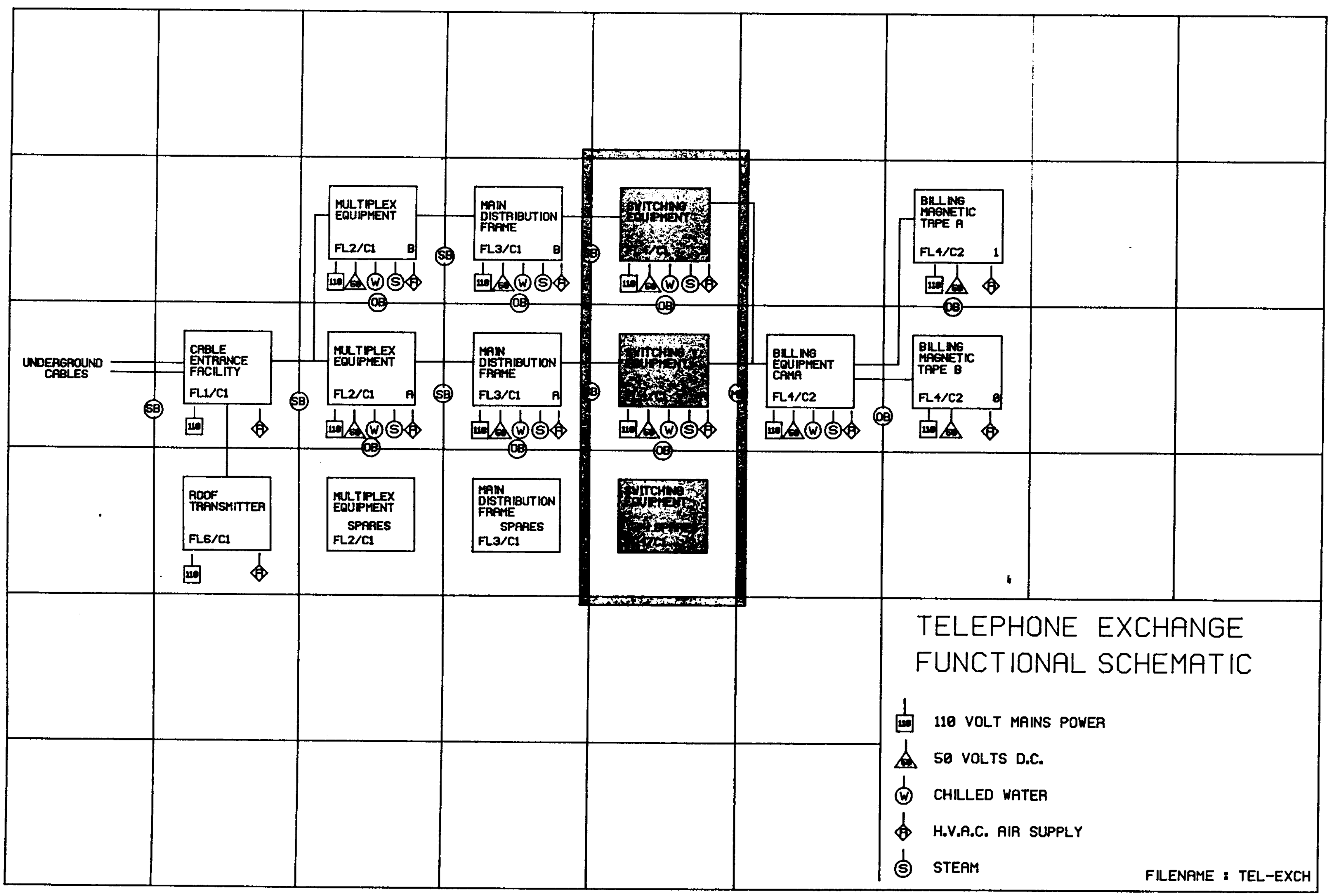


FIGURE 8-REDUNDANT EQUIPMENT IN SAME COMPARTMENT

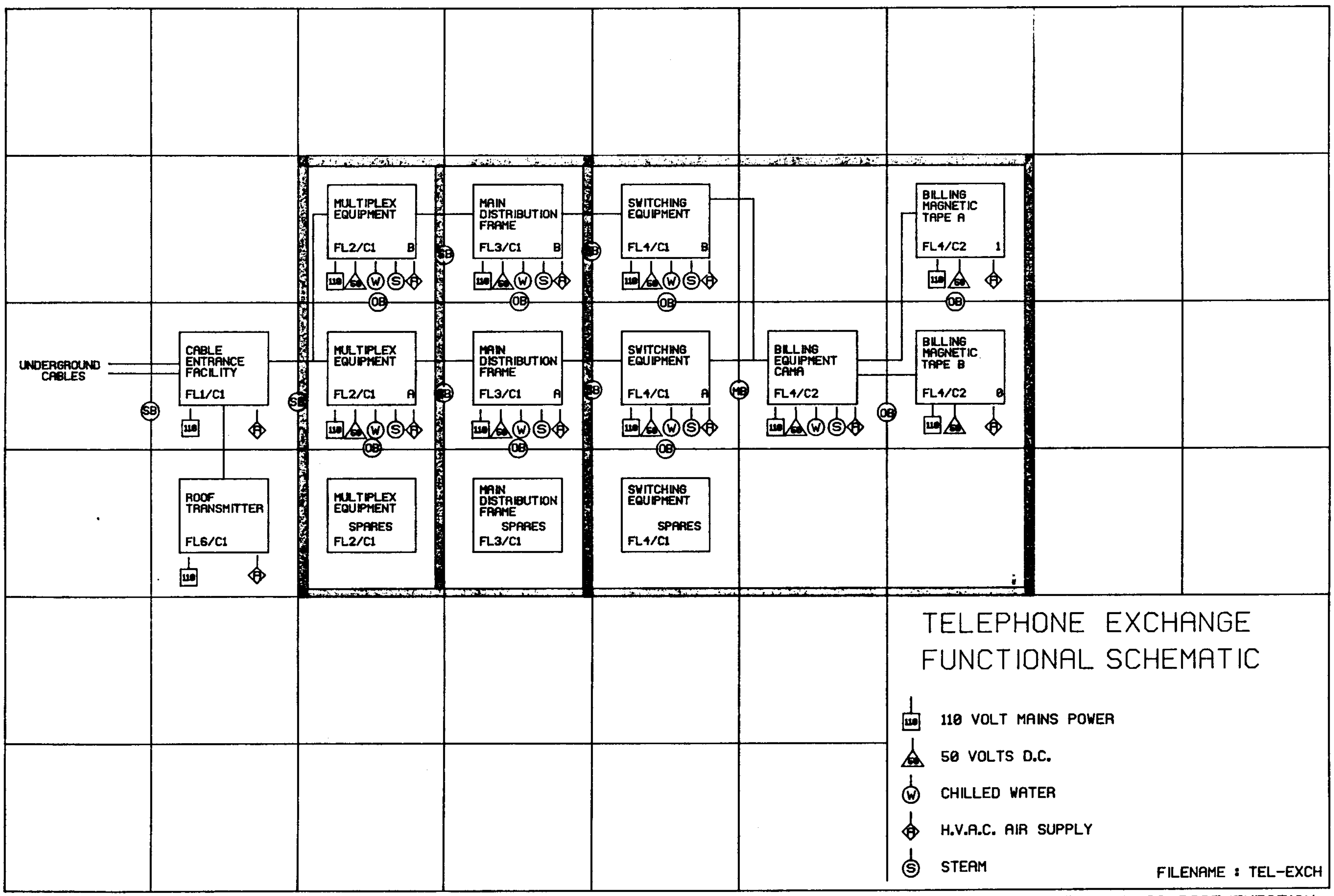


FIGURE 9-TYPICAL COMPARTMENTATION OF TELEPHONE EXCHANGE

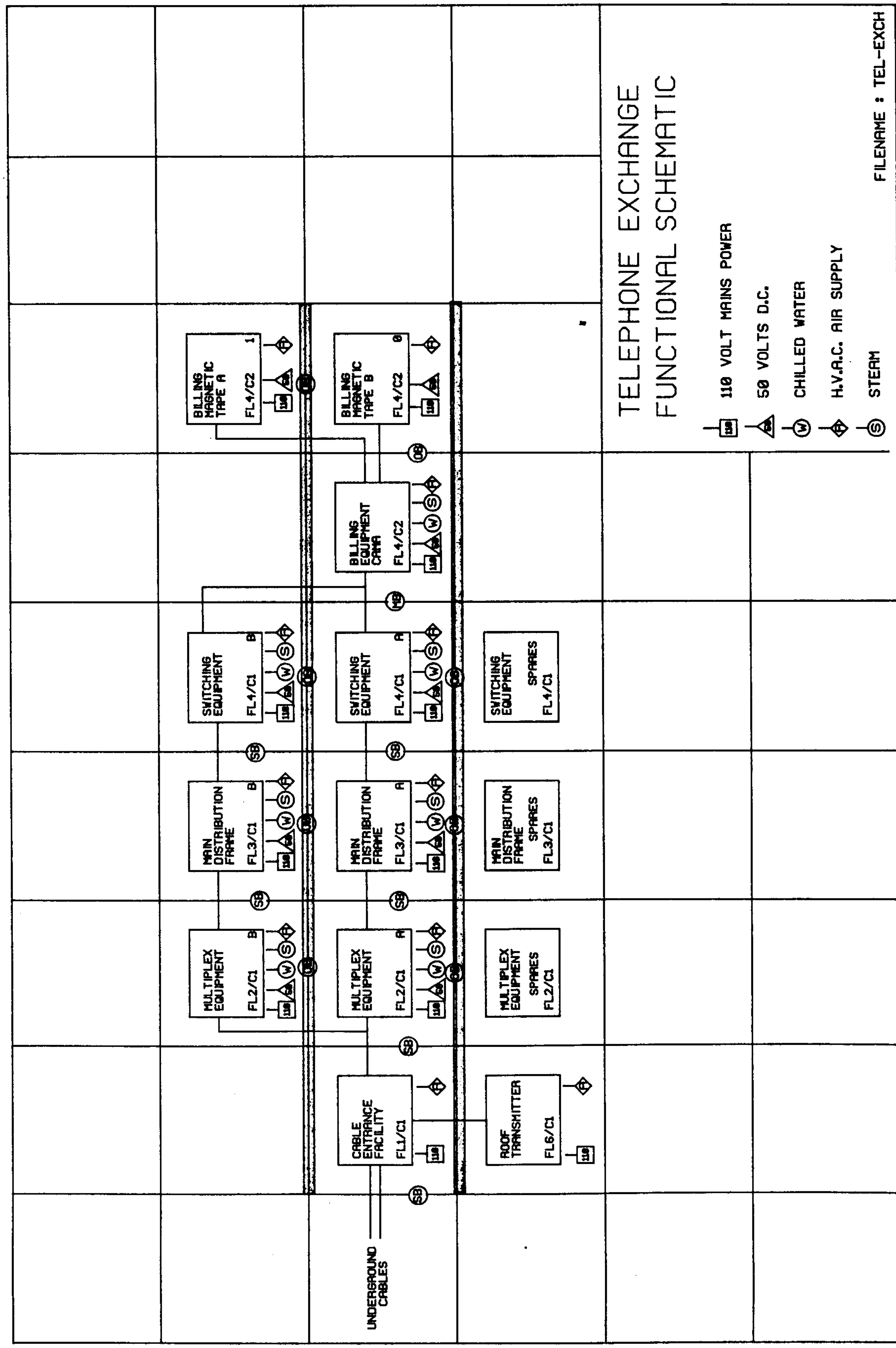


FIGURE 10-ALTERNATE COMPARTMENTATION
BETTER RELATED TO EXCHANGE FUNCTION

cable pairs coming into the cable vault (CEF) from those subscribers often are duplicated yet contained in the same cable sheath. Therefore, they can not be separated physically. However, for toll offices with cables carrying signals to other offices, it would appear to be prudent practice to consider separating the cable pairs into 2 or more groups and subdividing the cable vault. In that way, a fire destroying part of the vault would not totally interrupt the exchange's operation. It would also reduce the size of any potential fire, and make that fire easier to extinguish or control.

6.5 Choice of Fire Protection Alternatives

Miller [20], writing in 1973, suggested that the selection of fire protection systems needs to be based upon their cost/effectiveness in matching the risk. This seems a very important principle that could equally apply to protective systems guarding against losses from other perils.

For many telephone exchanges, the primary risk objective may be to ensure minimum interruption to exchange operations. For example, no loss of service to subscribers of greater than 12 hours may be the B.I. objective. In this context, the schematics show clearly that certain telephone equipment areas are CRITICAL and must not be lost if downtime is to be restricted. What also is clear is that the services equipment supplying that critical telephone equipment is, itself, also CRITICAL.

A particular example in exchanges is the role of HVAC refrigeration equipment (chillers). Telephone equipment, particularly the new digital switching gear, is often only guaranteed to function properly for temperatures in the range 0 - 45oC. Digital switchgear also may malfunction for rates of temperature change greater than 15oC/hr. [21] Since the equipment generates substantial quantities of heat of the order of 300W per square metre of floor area [21] , it is absolutely vital that the heat generated be removed to avoid temperature buildups that could cause equipment damage or automatic, self-protecting shut-down.

In order to avoid interruption to operations due to overheating conditions, telephone exchanges typically have two or more sets of refrigeration equipment. Each chiller usually is capable of carrying either all or a substantial proportion of the building cooling load. The chillers, however, are often located in the same compartment of the exchange.

The current approach to fire protection of chillers in the telephone industry is to treat them in the same manner as any other occupancy - they would not be considered a CRITICAL element. The Factory Mutual Data Sheet [7] on telephone exchanges, for example, makes no mention of refrigeration equipment.

The compartment housing refrigeration equipment would probably be fitted with heat or smoke detectors, and often fire insurance recommendations would call for sprinkler systems or total flooding, gaseous extinguishing systems. However, from a functional and operational viewpoint, it is more important that if one chiller is lost, the fire does not spread and damage the other(s). Thus, a fire rated partition separating the chillers, together with detectors and hand extinguishers, may be a far more cost/effective approach and more appropriate to the risk.

6.6 Effects of the New Telephone Technology

Telephone exchanges have undergone a tremendous transformation in the last few years due to the introduction of digital microprocessor based equipment. Large sections of the older electro-mechanical equipment are now being replaced with computer type equipment that occupies far less space. The result has been an industry move worldwide towards building smaller exchanges. Alternatively, where exchanges already exist, the trend has been to reduce equipment areas to a limited number of floors or sections of a building. The remaining floors or areas are then left empty or are rented to other parties.

The effect of these changes is to substantially modify the level of risk both in terms of property damage and business interruption. The new equipment tends to be much more expensive per square foot of floor space occupied. Also it is considerably more susceptible to damage by heat and smoke and perhaps by water [22]. The effect of water on digital equipment is a major area of controversy. This uncertainty only serves to complicate any risk decisions relating to telephone exchanges.

It is now a common practice to install telephone equipment in one room that will perform all the following operations:

- carrier/multiplexing
- call switching
- billing/records
- exchange diagnostics/maintenance
- equipment/operator control interface

Formerly, some or all of these functions would be performed by equipment located in different compartments separated by fire rated partitions.

The effect of concentrating equipment into one area is to open up the possibility of much greater property damage in dollar terms from a single incident. Exchange designers do not seem to have recognized this aspect of risk in the more recently constructed exchanges ; nor is it reflected in recent books or papers on the subject of exchange design and risk assessment. As well as property damage, the risk of substantial business interruption is also increased tremendously, although by how much is not certain. No-one in the industry appears to have a satisfactory method for establishing potential B.I. losses.

The question of redundancy and its effects on system performance is again raised by the advent of this new digital equipment. Previously, redundant switching equipment was on different floors or it was at least separated by some considerable distance if located in the same area. Now redundant switching equipment or central processing unit modules may be in the same cabinet, or even on adjacent racks within the same cabinet. The potential for a 'common mode failure' due to fire or other peril is significantly increased. Unfortunately, recent papers on redundancy in digital telephone equipment design do not address this problem [6]. To separate redundant sections, particularly for the new digital equipment, is probably prohibitively expensive unless designed for the purpose from the beginning.

All of this suggests that telephone equipment designers cannot operate in isolation. There needs to substantial design input from operations people, risk managers and safety specialists if large losses are to be avoided in the future. At present, a great deal of research, design and purchasing effort goes into acquiring 'highly reliable' telephone equipment. Often sophisticated fault tree analyses or reliability studies are conducted on the equipment. Equipment is tested to very tight reliability specifications. However, as Miller [20] suggests, when it comes to installation, these 'highly reliable' systems are often situated so that both primary and redundant equipment are subject to the same hazard. Therefore, the high level of system reliability sought is lost.

One further example of this is the CAMA (Central Automatic Message Accounting) computer equipment found in many exchanges in the US [4]. This computer monitors details of telephone calls through the exchange and stores it on magnetic tapes. This data is then combined with subscriber address deteils at a customers records center which generates customer bills. CAMA equipment is usually duplicated but the two computers typically sit 3 or 4 feet apart - a small fire, flood, or other incident would probably destroy both simultaneously.

6.7 Common Services

A further area of risk in telephone exchanges that the critical areas procedure of Appendix A highlights are the common services that often share the same sections of the building. This is clearly demonstrated in sectional views of an exchange showing the physical arrangements of HVAC ducts, water pipes etc.

In some exchanges, conditioned air is supplied from a central HVAC plant to all equipment areas. Alternatively, chilled water (and sometimes steam) is supplied to all floors for use by modular HVAC units on each floor or in each equipment area. In most cases these services run up the building in a services chase or shaft. Figure 11 shows the typical arrangements.

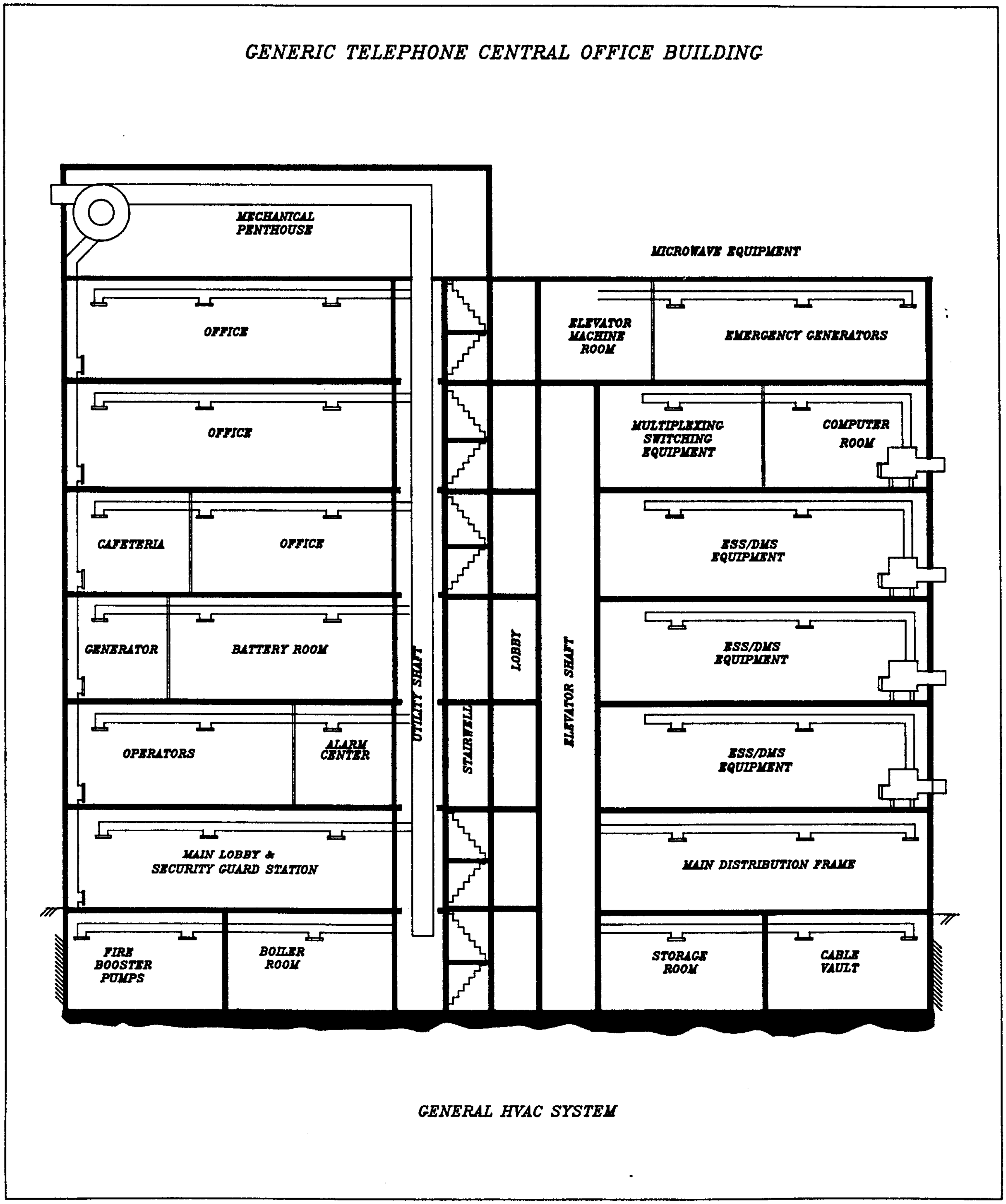


FIGURE 11-HVAC SYSTEMS SHOWING COMMON VERSUS MODULAR APPROACH

These shafts or small rooms carrying these services are often not viewed as that important. However, a fire, explosion, or other incident could destroy services equipment, such as the main chilled water pipes, and totally interrupt exchange operations.

Of even more concern, perhaps, are HVAC ducts. Common ducts carrying air to or exhausting from each floor provide the avenue for a fire in one area to spread heat and smoke into other areas. Ductwork passing through fire rated barriers are usually fitted with fire dampers. However these dampers usually require a good deal of heat to actuate their slow-acting thermal links. With corrosive smoke from PVC and other plastics considered a major hazard in an exchange fire [23], the lack of SMOKE dampers and often inferior performance of duct smoke detectors provides the possibility of damage to a wide area of an exchange.

Again, this discussion suggests a design philosophy for HVAC based on functionally independent systems in each equipment areas. Obviously, the relative cost of this approach compared with the traditional partially or fully centralized HVAC systems should be examined along with the benefits of an expected reduction in losses.

6.8 <u>Tenant Exposure</u>

The question of design of HVAC and power systems becomes even more important where buildings are shared by a telephone company and others tenants. As mentioned previously, the reduction in telephone equipment size is leaving empty space in many telephone exchanges that is very tempting to rent to other occupants.

The impact on telephone exchange operations could be great where other occupants share HVAC, power, water, fire suppression and other services. Serious interruption by other occupants to power and water supply may represent an undesirable increase in risk to the exchange. Probably more important is the possible infiltration of smoke or heat from fires in the other occupancies through shared HVAC plant and ducts. Where modifications to HVAC systems are being made for new telephone equipment and/or occupants, consideration should be given to isolating services to minimize this exposure from tenants.

7 LOSS DATA FOR TELEPHONE EXCHANGES

7.1 General

Use of the critical areas procedures described in Appendix A will generate some qualitative aspects and a 'feel' for the risk involved. Ideally, such a procedure should also form the basis for more detailed quantitative risk determination.

However, for this type of analysis, some statistical loss data is required in order to establish :

- frequency of loss
- severity of loss
- expected loss scenarios

While the emphasis in this work has been given to fire losses, there is no reason why the critical areas procedure should not be used as a framework for examining losses due to other perils. A good risk management programme considers all exposures - comprehensive checklists such as those by Church [8] have been found useful.

The literature cites a wide range of perils and hazards that have been responsible for losses in telephone exchanges. Braun [24] provides an excellent review of data on fire losses from a number of U.S. organizations. Crnkovich [25] also discusses fire, as well as a number of other exposures for telephone exchanges. These include :-

- windstorms
- adjacent hazardous occupancies
- flooding
- security risks - arson, terrorism
- lightning, other electro-magnetic interference
- power surges

One other peril, very important in areas such as Western U.S.A. and Japan, is earthquakes.

7.2 Flooding

Flooding and consequent water damage is a well known cause of loss and at least four scenarios are possible :

- flooding by local rivers, streams
- flooding from external utility water mains
- water pipe breakage inside the exchange
- water damage associated with fire suppression

The extent of recovery of telephone equipment after flooding is arguable. Crnkovich [25] suggests that equipment wetted by automatic sprinklers can be dried with an airhose, and service restored in a few hours. Conversely, Blain [26] cites the well-founded dread in the industry of the damage that water may cause to delicate communications equipment.

Two reported incidents highlight the potential for water damage due to flooding :

- Factory Mutual [7] report of flooding from a stream filling a telephone exchange with water to a depth of 5 feet - the receding water left one foot of mud in most of the building with over 3 feet of mud in the cable vault.
  Total loss : $750,000.

- A standpipe burst in a telephone exchange of the Chesapeake and Potomac Telephone Co. in October 1985. A total of 38,000 customers were affected with an estimated cost of repair of $400,000. [27]

Some statistics from one telephone company [28] help to put the potential losses from flooding in perspective with fire losses. Table 1 shows the comparative figures for a recent 3 year period.:

Peril	No. incidents	Total losses ($)	Mean loss ($) per incident
Fire	23	770,000	33,460
Flood	6	811,093	135,182

TABLE 1 - Fire vs Flood Loss Experience

Flooding is obviously a significant peril which must be given close attention by telephone company risk managers and building designers.

7.3 Fire Losses - General

As indicated earlier, probably the best general review of fire losses in telephone exchanges was done by Braun [24] in 1981.

His sources of data included :-

- National Fire Incident Reporting System (NFIRS), 1976-1979
- National Fire Protection Association (NFPA), 1960-1981
- Bell System statistics (Eckler - 1971-1977)

What is illustrated in this review and in some other sources of data [29] is that there is no standard basis for reporting telephone exchange fire losses. Some measures quoted in the literature are:

- average no. of fires per annum
- loss per fire incident
- loss per million square feet of exchange floor space
- total annual losses
- ratio of annual losses to company assets

Two other problems arising in any review of available data are:

(i) Losses in central office telephone exchanges are often hidden among losses to external plant, vehicles, information centres, ordinary offices and manufacturing plants in overall company figures.

(ii) Some figures include business interruption losses as well as property damage. Often, however, the basis of the figures is not stated.

Very little comprehensive statistical data is available in published form since 1980. With the tremendous technological changes occurring in the industry, the older loss figures are perhaps not true reflections of the most recent history nor likely to be particularly useful in predicting future losses.

7.4 Fire Frequency and Severity

Major fires in telephone exchanges are rare events. However there are significant numbers of smaller fires in large telephone organizations to permit some statistical analysis.

Eckler [30] examined some 1500 fires that occurred in buildings of the U.S. Bell System during the period 1971-1977. The basis for reporting of those losses was 'dollars of fire damage' - this appears to be solely related to property replacement cost - no business interruption costs are included.

The majority of Bell's fires were small with 58% of cases not even requiring the fire department to be called. The losses were shown by Eckler to generally follow a log-normal distribution, except for the 1975 New York exchange fire in which property losses exceeded $60 million. The analysis showed the mean loss per incident to vary with the year but range from $5000 to $13,000. This mean loss statistic is biased by a very few high loss fires. A better measure may be the median (most common) loss which Eckler found to vary between $30 and $80.

Telecom Australia data [29], shown in Table 2 below, gives mean losses per incident for telecommunication facilities that are of the same order as those for the Bell System.

Period	No. fires	Total Losses ($Aust.)	Loss per incident ($Aust)
1978-1980	31	279,124	9,004
1981-1982	62	118,513	1,911

(for period, $1 Aust = $1 US approximately)

TABLE 2 - Telecom Australia Fire Losses

What these figures show generally is that, while there are quite a number of fires in telephone exchanges, the vast majority are small and the mean loss per incident is very low. What is not shown in these figures is the direct loss of revenue or other more subtle business interruption losses. These may be quite substantial even for small fires. On the other hand, some fires may cause damage but no interruption to service because of the available capacity of redundant equipment.

7.5 Better Measures of Loss

Loss statistics having some sound financial basis would be more appropriate for decision making at the risk management level. While not totally satisfactory, some sources [11,28,29] do exist that relate frequency or severity of fire losses to the assets or size of the organization.

One measure is fire loss expressed as a percentage of company investment - the so-called loss/investment ratio. In most cases this appears to mean property damage losses, due to fire, expressed as a percentage of some book value of property and equipment assets. Table 3 shows comparative figures for three telephone organizations.

Organization	Period	Fire Loss/Invest.Ratio (%)
Bell System	N.A.	0.001
Indep. U.S.Co.*	1983-85	0.00017
Telecom Aust.	1973-74	0.0003

* Includes B.I. losses

TABLE 3 - Fire Loss/Investment Ratios

While a direct comparison of figures has no meaning because the exact basis of calculation is unknown, the figures show that the losses are extremely small as a percentage of capital investment.

This low loss/investment ratio leads to a major conflict with insurers. A large telephone company may be able to sustain a $50 million uninsured loss, for example, because of its economic base. However, such a loss to an insurance carrier, even with the usual reinsurance support, may be catastrophic in terms of the insurers long term financial security. Therefore the insurer may attempt to press upon the telephone company a range of fire protection requirements that are not economically reasonable from the loss/investment ratio or risk management viewpoint of the telephone company.

Another useful figure developed by Eckler [30] relates fire frequency to floor area. He normalized fire losses by developing figures for the number of fires per million square feet of floor space in the Bell System. The result was an overall fire frequency of approximately 0.6 fires per million square feet per year for internal building fires.

This result for Bell telephone exchanges fits well with three risk categories developed by Factory Mutual [31] for U.S. Naval properties. These categories are shown in Table 4.

Risk Category (fires per million square feet per year)	Typical Occupancies
less 1	telecom facilities, EDP, offices, schools
1 - 3	manufacturing, laundries, cafes, stores
more 3	gas stations, power plants, clubs, homes

TABLE 4 - Risk Categories

Eckler also subdivides fire frequencies into categories of building function and presents the following rough estimates as shown in Table 5.

Function	No. fires/million square feet/ year
Switch rooms	0.3
Power rooms	1.0
Cable vaults	0.2
Community dial offices	0.5
Repeater/Microwave Stations	1.0

TABLE 5 - Bell loss frequency normalized by floor space

This data, together with mean or median loss per incident information given earlier, provide at least a crude method of estimating annual property losses due to fires in a telephone exchange.

The loss estimate, somewhat similar to the one developed by Rutstein [32], would be calculated by the formula

$$P = \left(\sum_{i=1}^{N} f_i A_i \right) \times \bar{L}$$

where P = annual property damage (dollars)

f_i = frequency of fire per million square feet per year for building function i (ft year)

A_i = area of building function i (square feet)

$\bar{L}$ = mean loss per fire incident (dollars)

i = building function identifier (Table 5)

7.6 Origin and Cause.

Braun [24] provides an analysis of the incident data from the National Fire Incident Reporting System (NFRIS) on telephone exchange fires. A total of 189 fires were reported for the period 1976-1979. Of these, 59% occurred outside buildings. This suggests that external exposures are a major factor to be considered in design of exchanges and their outside facilities.

Of the internal U.S. exchanges fires documented by NFIRS and studied by Braun [24], 42% were caused by short circuits or arcing. What is surprising is that about 34% were caused by smoking materials. Telecom Australia figures [29] for 1978-80 show likewise that electrical arcing/overload is the principal cause at 30%, although open flame (often due to arson) is also a major ignition source. What is different in Australia is that smoking materials represented only 5% of ignitions, presumably because of different policies on employees smoking in exchanges.

Both the NFIRS and Australian figures highlight the fact that most internal fires start in electrical or electronic equipment. Braun [24] reports that the majority of these fires (53%) start in electrical distribution (power) equipment rather than electronic telecommunications equipment. NFPA incident reports [24] and FM Loss Experience [7] confirm this, citing examples of :-

- power supply cable failures
- battery accidents
- electrical equipment cabinet fires.

Eckler's [30] estimates of 1.0 fires per million square feet per year for power rooms, compared with 0.3 for switch rooms and 0.2 for cable vaults, also seems to be in agreement with Braun's findings.

7.7 Flame and Smoke Spread

Crnkovich [25] states that fire spread in telephone equipment is slow, although Factory Mutual [7] suggests that the physical arrangements of distribution frames, for example, favours propagation and severe fires can result.

Many test protocols, documented by Braun [24], are carried out by telephone companies to limit fire propagation along wires and cables, and through equipment. This low fire spread seems to be confirmed by Eckler's[30] study in which 58% of fires never grew to a size that warranted fire department attendance. Braun's NFIRS analysis showed that in 54% of cases, flame spread was limited to the object initially ignited. In only about 15% of cases did flame spread beyond the room of origin.

Smoke spread is probably of even greater importance in exchanges. Blain [26] comments on the well-known effects of corrosive smoke from burning PVC insulation and suggests that even if a fire is confined to a distribution frame, all other equipment in that room may well be ruined.

This greater spread of smoke than flame is confirmed in Braun's analysis, where nearly 50% of the time, smoke damage spread beyond the initial item involved.

7.8 Fire Suppression

Given the low fire spread rate and the small median loss figures in telephone exchanges , it might be expected that most fires would either self terminate (often due to power disconnection) or be suppressed by hand extinguishers. Australian figures [29] confirm this - see Table 6.

Extinguishing Method	% fires extinguished	
	1978-80	1981-82
Burned out (self term.)	10	26
Hand extinguishers	36	32
Hose reel	8	7
Fire hose	24	15
Other	22	20

TABLE 6 - Methods of Extinguishment - Telecom Australia

Hand extinguishers are also the most often used suppression device in U.S. exchanges. Eckler [30] reports 56% of fires being suppressed by hand extinguishers or hose reels without fire department assistance being required. This obviously supports the Bell approach of manual suppression, with readily available hand extinguishers, advanced by Hession [33].

The controversy over the choice of automatic sprinklers, halon or manual suppression continues to rage. Crnkovich [25] and Factory Mutual [7] argue the effectiveness of automatic sprinklers in protecting high value telephone equipment. Factory Mutual, however, now also recognises halon systems as being effective in properly sealed, non-combustible structures. Sielert [34] argues against sprinkler protection suggesting that GTE's extensive research shows :

(i) water can have disastrous results on telecommunications equipment

(ii) major equipment damage and massive service interruption would still occur with sprinklers

(iii) Halon protection is the most appropriate measure for telephone exchanges.

Finally Hession [33] argues that, on a low risk occupancy like telephone exchanges, automatic suppression is not warranted at all. He favours, as suggested previously, a good detection system, and manual suppression by trained exchange personnel.

Little statistical evidence for the effectiveness of suppression systems in telephone exchanges is available. However, Table 7 shows a recent analysis [28] which provides some evidence of the effectiveness of halon in exchanges over a 16 year period.

	No. fires	Total losses (US$)	Mean Loss /incid.(US$)
No protection	8	3,511,273	438,909
Smoke detectors/ halon	24	157,916	6,580

TABLE 7 - Halon Effectiveness

No comparison of the effectiveness of halon versus sprinklers in protecting telecommunications equipment appears to be available. However, some studies have been done on computer equipment that is quite similar and could be expected to have a similar loss potential.

Johnson [35] used Factory Mutual, US Government and other loss statistics to estimate average sprinkler protected and halon protected losses of computer equipment. This was then supplemented with a simplified damage analysis, based on convective heat release rates from combustion of electronic equipment. The results are shown in Table 8:-

Protective System	Average Loss Expectancy
Halon	$ 20,000
Sprinklers	$ 100,000 - 150,000

TABLE 8 - Computer Losses, Halon vs Sprinklers

Reliability of the respective systems is another major argument that was included in a computer fire risk evaluation by Bissell, Chutoransky and Crowley [36]. They showed the lower level of damage expected with Halon systems. However, through a Farmer's Curve of probability versus severity of losses, they showed that chances of a very severe loss with sprinklers is less than with Halon because of the greater reliability and continous, rather than one shot, suppression action of automatic sprinklers.

7.9 Fire Incident Reports

As a supplement to loss statistics, fire incident reports help to provide a picture of possible fire scenarios important to most quantitative risk assessment methods. Many such reports on telephone exchange fires have been prepared by the National Fire Protection Association (NFPA), and are listed by Braun [24].

A brief summary of some of the more serious fires demonstrates the potential for loss. In particular, they highlight the possible serious interruption to subscriber services.

1. In the early sixties a fire occurred in a major telephone exchange in Australia's capital city, Canberra. The cause was arson and the damage ran to about AUST$2 million. Snelling[37] reports that some essential lines to Parliament House and some Defence facilities were maintained, but private lines to homes and businesses were disrupted for several weeks.

2. A major fire also occurred in the Zurich-Hottingen telephone exchange in 1969. Again, arson was the cause resulting in major damage due to the burning of PVC insulated

cables. Wuthrich[38] reports that corrosive, hydrogen chloride laden smoke spread to many areas untouched by flame. At one point, it was thought that it might have been necessary to demolish the exchange building due to corrosive attack on the reinforced steel and concrete structure. However, post-fire chemical analysis, reported in detail by Wuthrich, showed that, while corrosive products had penetrated paint coatings, plaster, and the concrete itself, the building was still structually sound.

3. In Barcelona, Spain, during 1973, a fire occurred that grew to such proportions that it threatened the whole structure of the exchange [39]. The fire started on the 6th floor of the steel frame building, burning initially in bundles of PVC sheathed telephone cables. It spread upwards through unstopped cable penetrations while telephone company officials and fire department officers argued over the effectiveness, and potential damage, to other telecommunications equipment of carbon dioxide, foam, and ordinary hose lines. This delayed the suppression effort and the fire spread to the 7th and 8th floors. It finally took some 12 hours to extinguish.

4. The New York exchange fire of February 27, 1975 is perhaps the most famous. It occurred in downtown Manhattan and interrupted service to 170,000 subscribers. Lathrop [18] reports that the fire apparently started in the cable vault and remained undetected for some time. With no automatic suppression system installed, the fire spread vertically, via

cable penetrations, to the main distribution frame and switching equipment on the two floors above. The intensity of the fire and the tremendous quantities of corrosive, toxic smoke, given off by PVC insulated cables particularly, made fire fighting very difficult. As a result, the fire burned for 16 hours before final extinguishment. Many businesses, as well as private individuals, lost their telephone service. Major emergency service communication links for ambulance, police and fire departments were also lost, some for more than 24 hours.

5. Another more recent example [40] of a seemingly small fire, easily extinguished but having major consequences, occurred in Hawaii in 1982. The fire occurred in a 40 feet by 50 feet concrete block building housing local telephone equipment. The facility was unmanned and had no detection system. The fire apparently started in power equipment, already shown statistically as a major fire cause. The fire itself did not grow significantly, and was easily extinguished with 2 carbon dioxide and one dry chemical hand extinguishers. However, it filled the building with dense smoke, deposited soot on all exposed equipment surfaces, and caused damage estimated at $2.3 million. No figure for business interruption losses was given.

There have been a number of other major telephone exchange fires around the world, such as the recent one in Japan mentioned previously [1]. Telephone equipment can burn and major fires, while rare events, can have major consequences both in terms of property damage and interruption to service.

8. MORE DETAILED RISK ASSESSMENTS - USE OF CRITICAL AREAS PROCEDURES

8.1 General

As has been mentioned previously, there are many different methodologies and a wide range of terminologies used in the risk assessment field. These techniques have been developed in areas as diverse as the chemical industry, the nuclear industry, medicine, toxicology regulation and road accident studies. Only recently, reports Moghissi [41], have attempts been made to put the whole discipline of risk assessment on a firm fundamental basis having a uniform terminology.

Moghissi [41] defines risk assessment as the 'scientific process of assigning the probability of an adverse effect to an action or a situation'. In relation to telephone exchanges, risk assessment might be more properly described as the method of finding the probability of a specified loss, that loss being expressed either in terms of damage to equipment or interruption to exchange operations. Risk assessment produces the basic data upon which decisions such as acceptable design alternatives, cost/benefit analyses, or recommended solutions can be made in a risk management programme.

The critical areas procedure developed for telephone exchanges in this thesis forms the first part of any risk assessment. It provides a means of describing the system that is to be analysed. That is, it identifies 'what is at risk'. Figure 1 previously showed that there are a number of other steps in this process of establishing the risk of loss, whether it is expressed in qualitative terms or in terms of probability of loss. This section of the thesis, therefore, is devoted to an examination of some different risk assessment methods, an evaluation of their suitability to telephone exchanges, and an investigation of the usefulness or applicability of the critical areas procedure to risk assessment methods.

Risk assessment methods suited to commercial/industrial buildings or facilities are principally of two types :

(i) those providing a rating in order to rank different plants or parts of a facility.

(ii) those providing a quantitative probability of loss in a particular plant or facility.

Both of these areas will now be examined, although the emphasis will be given to quantitative methods, most of which are suitable to analysis of either existing buildings or new facilities. Tuler [14] suggests that these analyses should be additional to, rather than a substitute for, other more traditional approaches to safety management.

8.2 Rating Measures

Simmons and Tyler [42] and the CONCAWE group [43], in their reviews of risk assessment techniques used in the chemical and petroleum industries, provide details of so-called 'hazard indices'. These enable different plants to be ranked on the basis of potential hazards, particularly explosions, fires and toxic releases.

The best examples of these hazard indices are the Dow Index [44] and the Mond Index [45]. Each plant is subdivided into smaller areas and ratings are given for the types and amounts of materials used, operating conditions and plant layout as well as plant safety measures. The end result is a rating on a 'calibrated' scale of risk classification ranging from 'LOW' to 'CATASTROPHIC'. These measures are flexible in their use and can be used by non-specialists. Unfortunately, however, they are of little use outside the chemical industry for which they were designed.

A more general technique, on which the above indices were probably based, is the DELPHI method. This method uses a so-called 'Delphi' group of experts from a variety of related fields to develop a procedure for evaluation in any given field. The method has a number of steps, including :

(i) identification of major factors leading to loss
(ii) identification of desirable safety measures
(iii) weighting of potential loss and safety factors
(iv) determination of a 'norm' against which all future assessments are made.

(v) calculation of rating of risk at any given building, facility or location in comparison with the 'norm'.

The method of determining risk is obtained through repeated resolutions of divergent opinions that ultimately produce a common agreement within the Delphi group . Once completed, a number of facilities can be ranked in terms of their risk rating. Then recommendations can be made to increase safety at those facilities of higher risk through removal of potential risk factors and/or addition of supplemental safety measures.

One example of this 'Delphi' technique is the 'Firesafety Evaluation System for Health Care Occupancies' in the NFPA Life Safety Code [46]. A similar one, that reflects slightly different conditions in a different country, is the UK 'Fire Safety Evaluation (Points) Scheme for Patient Areas within Hospitals' [47]. This was developed by the Department of Fire Safety Engineering at the University of Edinburgh for the UK Department of Health and Social Security.

This 'Delphi' technique could be used for simply ranking the different exchange locations of a telephone company. They could be ranked on the basis of risk of loss from fire, flood, earthquake, etc., or some combination of these. It would then enable the telephone company to direct its limited resources towards those locations most at risk.

The critical areas procedure developed in this rpoject would seem to offer some benefit to a 'Delphi' group working on this type of risk assessment technique for telephone exchanges. Once the critical areas procedure had been applied to a small number of different telephone exchanges, it would provide the basis for determination of the risk parameters and highlight some of the safety factors involved.

In the case of fire interrupting exchange operations, for example, some of the questions on risk factors that would become obvious immediately are:-

- is redundant equipment adjacent?
- is the cable vault separated from services equipment?
- are power cables separated from signal cables?
- is there redundant refrigeration capacity ?

Some questions concerning safety factors that influence the risk assessment may be likewise identified as :-

- are there fire walls separating redundant equipment?
- is the detection system fully operational?

8.3 Quantitative Risk Assessment Methods

There are now available a range of quantitative methods of risk assessment that may be suitable for estimating fire losses in telephone exchanges. All follow the same general pattern, and often use the same techniques. For example, fault trees and event trees are a common part of many methods. The objective of these quantitative methods is to characterize the risk as some probability of occurrence of a particular specified loss. In the case of telephone exchanges, this loss could be property damage or loss of revenue (business interruption).

The major steps of risk assessment, as outlined by Moghissi [41], are:

- engineering failure assessment
- exposure assessment (hazard identification)
- effects (consequences) analysis
- risk characterization

These steps are not carried out necessarily in the above order however. A flow diagram showing all the steps of risk assessment, in the order usually completed, is illustrated in the previously illustrated Figure 1.

The methods of risk assessment to be examined here are shown in the following Figure 12.

GENERAL RISK ASSESSMENT METHODOLOGIES

PLANT, FACILITY DESCRIPTION	ENGINEERING FAILURE ASSESSMENT	EXPOSURE ASSESSMENT (CRITICAL EVENTS)	EFFECTS/ CONSEQUENCES ASSESSMENT	RISK CHARACTERIZATION
HAZARD ANALYSIS—CHEMICAL/PETROLEUM INDUSTRY				
—PLANT MODEL —LINE DIAGRAM	—FAULT TREE (DIGRAPH) —LOSS STATISTICS	—FIRE/EXPLOSION —HAZOP —FMEA	—EVENT TREE —DECISION TREE	—FREQUENCY OF CRITICAL EVENT
PROBABILISTIC RISK ANALYSIS (PRA)				
—PLANT MODEL	—FAULT TREE (DIGRAPH) —LOSS STATISTICS	—CRITICAL AREA DETERMINATION —FIRE DAMAGE TO SPECIFIED AREA EQUIPMENT	—EVENT TREE —ACCIDENT SEQUENCES	—PROBABILITY DISTRIBUTION OF FREQUENCY OF SPECIFIED AREA OF DAMAGE
ENGINEERING METHOD FOR BUILDING FIRE SAFETY				
—BUILDING PLANS —PLANT MODEL	—IGNITION —FLAME SPREAD —SMOKE SPREAD —STRUCTURAL PERFORMANCE	—EGRESS OR DEFEND IN PLACE —PROPERTY DAMAGE —OPERATIONS CONTINUITY	—DECISION TREES	—PROBABILITY OF SUCCESS IN LIMITING FIRE, SMOKE OR STRUCTURAL DAMAGE

FIGURE 12

The methods are:

1. Hazard Analysis - basic technique developed in the chemical/petroleum industry
2. Probabilistic Risk Assessment (PRA) - developed principally in the nuclear industry
3. Engineering Method for Building Firesafety - developed at WPI by Fitzgerald for firesafety analysis of buildings

8.4 Hazard Analysis

This method of risk assessment started in the chemical/petroleum industry has been improved progressively with the introduction of components such as hazard and operability studies (HAZOP) [48] and failure modes and effects analysis (FMEA) [13].

As shown in Figure 12, the critical events in the chemical industry are usually fire and explosion. Often the size fire or explosion is not quantified as each is thought to be an undesired hazardous condition regardless of the size.

This form of analysis usually incorporates HAZOP and/or FMEA techniques to identify the critical events (often called HAZARD IDENTIFICATION) and fault trees to determine the failure mechanisms. Sometimes event trees are used to develop the accident sequences resulting from the critical events where the extent of damage, for example, is sought. Cause-consequence diagrams are another alternative approach incorporating both fault trees for cause of failure of components and event trees for the consequence of that failure.

The advantages of this general approach to risk assessment is that it is systematic, comprehensive, and particularly suited to mechanistic options. [43] It may be used qualitatively. Alternatively, fault trees can be quantified to give probabilities of occurrence of critical events, such that causative event sequences can be ranked in order of priority.

There are a number of disadvantages, however, that make this approach unsuitable for general risk assessment of fire losses in telephone exchanges. They are :

(i) the telephone operation, of itself, is not hazardous - failure of one component is unlikely to cause a major fire or explosion, as the loss statistics clearly show.

(ii) the probability of fire damage of a certain size is the objective. This is time and fire growth rate dependent and fault tree/event tree methodology does not handle these dependencies well [43].

(iii) fault tree development and quantification for an extremely complex operation like a telephone exchange is very time consuming.

There are, however, some situations in telephone exchanges where a fault tree risk assessment approach would be useful. An example would be loss of -48V DC supply to the telephone equipment due to mechanical failure of power supply equipment. The component failures could be considered on/off, mechanistic options and the extent of loss is not a consideration. If the DC supply to telephone equipment fails, exchanges operations cease.

The 'critical areas procedure' would show clearly the major power supply items involved, although not the important control circuits. A typical DC supply arrangement is shown in Figure 13.

A fault tree analysis with 'loss of DC supply' as the top event would perhaps provide some interesting insights into exchange power equipment design. While power equipment ignitions have been shown to be a major contribution to exchange losses, there are apparently no statistics on interruption to business due to loss of DC power as a result of component failures.

One aspect of fire protection that has been shown to benefit from a fault tree approach is reliability of water supply systems for fire fighting. Hasagawa and Lambert [49] conducted such an investigation on a supply for a major Californian laboratory complex. They used fault trees, enhanced by the directed graphs (digraph) methodology [50], and a detailed Failure Modes and Effects Analysis (FMEA). A similar approach

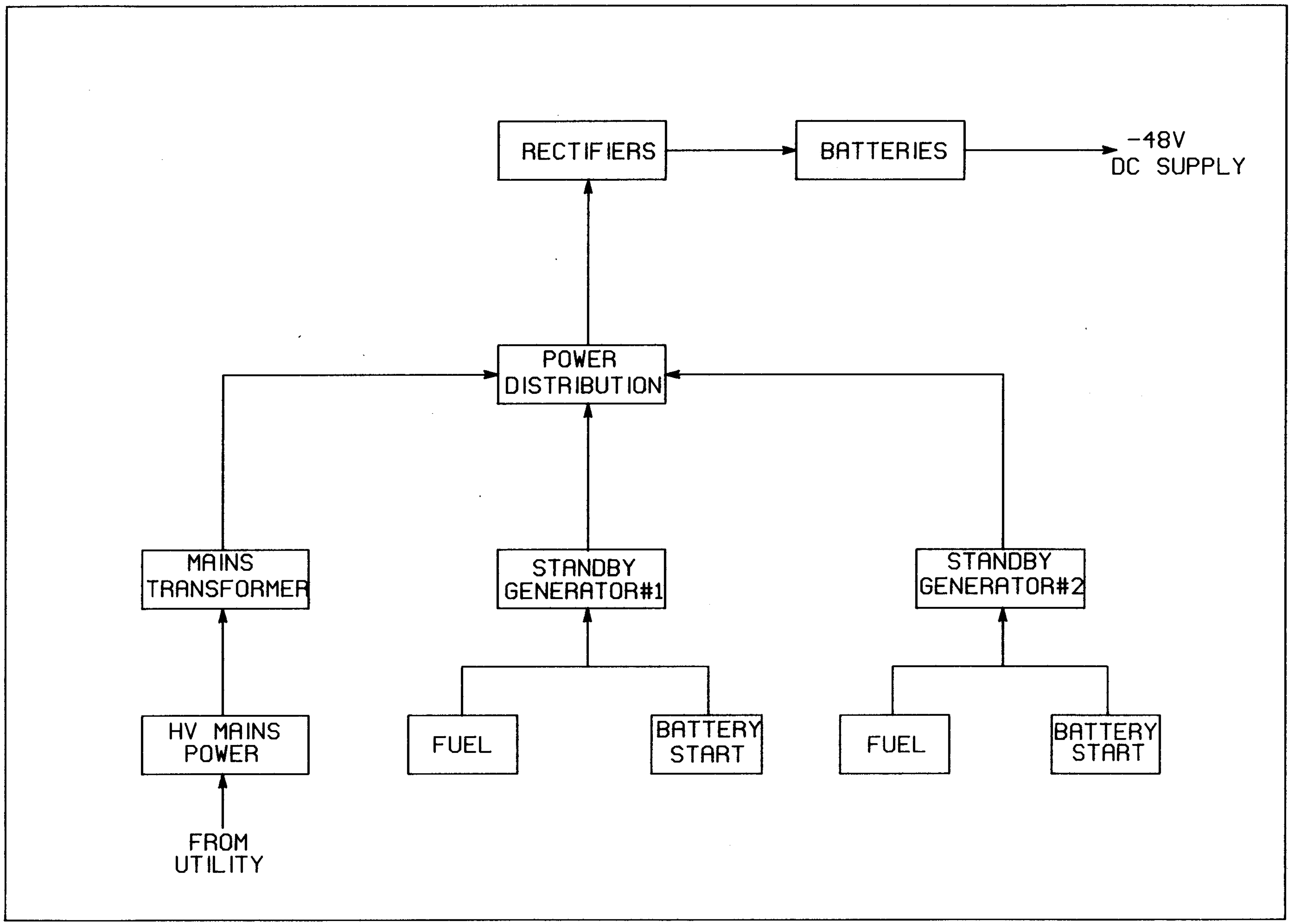


FIGURE 13-TYPICAL DC SUPPLY ARRANGEMENT

could be useful for telephone exchange water supplies for fire fighting or for HVAC cooling. Lees [13] provides a valuable reference source for component failure data that could be used in any fault tree quantification.

8.5 Probabilistic Risk Assessment (PRA)

Kazarian, Siu and Apostolakis [51] describe probabilistic risk assessment (PRA) as a systematic approach to risk quantification and identification of major accident scenarios that is suited to complex industrial facilities. It has probably been used most widely in the nuclear industry to examine risk of plant failure as a result of earthquakes, hardware failures, operator actions, and fires. It provides useful risk data which risk management can use to examine alternative designs or other options likely to reduce risk.

The advantages of PRA over some other methods is that it examines the consequences as well as the critical or initiating events. Taking fires as the peril, the typical PRA critical event is not usually fire ignition, but a level of fire damage necessary to cause substantial operational difficulties. Risk is then expressed as a frequency of this given level of fire damage. The uncertainty of results is also given prominence in the methodology as substantial reliance is still placed upon engineering judgement and statistical information in the analysis [16].

Since PRA relates frequency and severity, it seems well suited to risk assessment in telephone exchanges. In the nuclear industry, PRA has been particularly effective in examining the risk to redundant equipment located in the same compartment, and the potential for a 'common mode failure' [16]. This provided the inspiration for the development of a 'critical areas procedure' in this research that would highlight locations of redundant equipment in a telephone exchange where the potential might exist for simultaneous loss due to fire or some other cause.

The PRA methodology used in fire analysis by Kazarian et al. [16] has 4 major steps :-

(i) Identification of important fire related scenarios

(ii) Assessment of the frequency of fires

(iii) Assessment of the fraction of fires that damage critical components

(iv) Assessment of the conditional frequency of severe consequences, given damage to critical components.

It also has three ideas important to the quantification:-

(a) the occurrence of fires

(b) the physical effects of fires

(c) the response of the plant.

Step 1 of the analysis first examines the exchange for 'critical areas' i.e. those locations where a fire will have a major impact on exchange operations. The 'critical areas procedure' developed for telephone exchanges in Appendix A provides a systematic basis for identification of such locations. Typically, they are often locations where redundant equipment is located in the same compartment. For this example, let us choose a simplified arrangement of two major sets of redundant switching equipment in the same room - see Figure 14.

Once the critical areas are identified, different classes of fire scenarios are identified that, through simple event trees, can be shown to have a major impact on operations. Such fire scenarios affecting both switching sets might include:-

1. Fire (location X) that grows in Switch A and spreads to damage Switch B

2. Fire (location Y) that damages DC power cables in parallel cable trays

3. Fire (location Z) that starts in signal cables for switch A and spreads to signal cables for switch B

4. Fire that starts outside and propagates into compartment through HVAC to damage both switch sets.

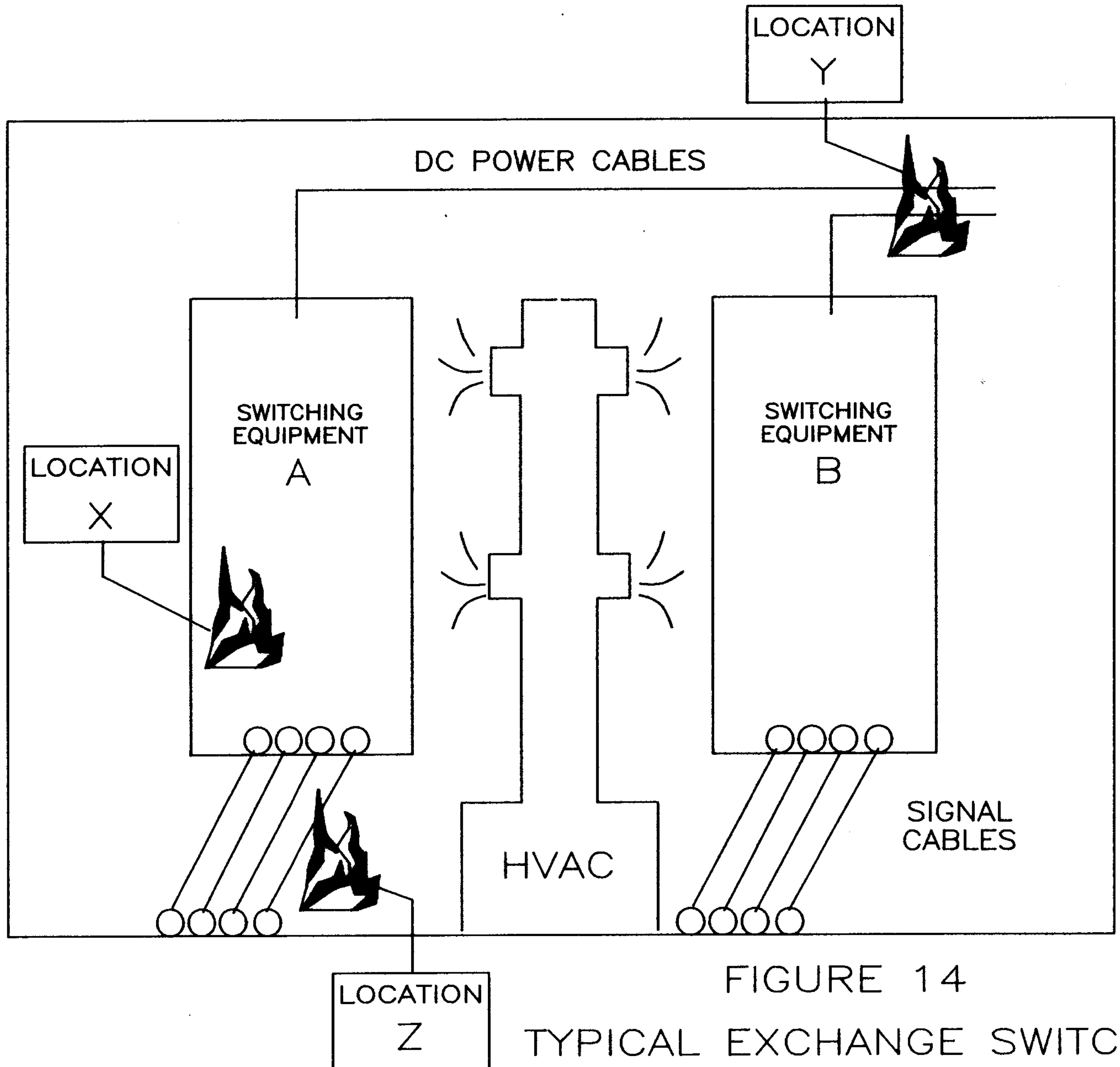


FIGURE 14

TYPICAL EXCHANGE SWITCH
PLAN VIEW

Kazarians et al. [16] suggest that usually not all scenarios need to be analysed in detail. A bounding analysis can be used to eliminate those scenarios where the contribution to risk is insignificant.

Step 2 of the procedure establishes the quantification of the frequency λ_X of each scenario. To illustrate the process, consider the first scenario of a fire spreading from switch A (location X) to switch B.

Then frequency of this scenario can be written as follows :-

$$\lambda_X = \lambda_P f_{SWR} f_{L,X} f_{D,X} f_{NS,X}$$

where

λ_P = annual frequency of fires in telephone exchanges

f_{SWR} = fraction of exchange fires in switch rooms

$f_{L,X}$ = fraction of switch room fires that occur in location X (in switching equipment)

$f_{D,X}$ = fraction of fires in switching equipment (location X) that are large enough to damage both sets of switching equipment (A and B)

$f_{NS,X}$ = fraction of those large fires that are not suppressed before damage to both switching sets.

The first two terms that identify the annual frequency of exchanges fires and the fraction in switch rooms are reasonably easy to quantify. However, the remaining factors represent an increasingly level of detail and become much more difficult to evaluate and quantify.

Steps 3 and 4 evaluate these remaining three factors and competing fire and suppression models are required to assess the frequency of fires growing from location X to damage the adjacent redundant equipment. In the nuclear industry, a temperature criteria for damage to cables and switchgear is used. However, for sensitive telephone equipment, other more appropriate criteria, such as particulate levels, smoke density, or corrosive gas concentrations, might have to be considered.

The result of the analysis of the scenario considered (Location X) would be a cumulative probability distribution for the frequency λ_X . Other scenarios would be similarly evaluated and the results summed to give the risk to exchange operations of fire in switch rooms.

From a risk management viewpoint, PRA can be used very effectively to look at options. Kazarians et al.[51] give a good example of its use in the nuclear industry. For the telephone exchange, the PRA analysis of each fire scenario making the major contribution to fire risk would be reassessed to include the effect of different safety measures. For the location X fire in the example cited, the base case for the scenario might be conventional telephone equipment and totally manual detection and suppression. Options that could be examined to see their effect on the frequency of damage to both switching sets (A and B) could be :-

- less combustible telephone equipment materials
- different physical equipment configurations
- increased separation distance between switches A and B
- construction of 1 hour rated partition between switches
- installation of automatic sprinklers
- installation of smoke detection and halon system
- direct connection of a manual alarm system to the fire department.

Telephone exchanges, therefore, would seem to be an ideal application of probabilistic risk assessment. The frequencies of specified losses and the effect of risk reducing options should be useful data for risk management decision making, and the 'critical areas procedure' developed provides a sound basis for such an analysis.

Some disadvantages associated with the method may be the uncertaincies associated with the risk frequencies, although it is doubtful whether they would be any greater than with any other method. A greater problem is that the methodology and development of physical, fire propagation and suppression models probably requires a high level of expertise in telephone exchange engineering, fire modelling and statistical risk analysis. Such risk assessments would be time consuming and costly. However, an analysis of one exchange, typical of many others, may determine operational, design and safety improvements that could be of general use throughout a telephone company's network of facilities.

8.6 Engineering Method for Building Firesafety

Another comprehensive approach suited to risk assessment of fires in telephone exchanges is the Engineering Method for Building Firesafety developed by Fitzgerald and Wilson (52]. This method extends concepts originally formulated by Nelson [53] into a comprehensive procedure by which the components of fire and buildings can be examined in an organized, systematic manner.In many ways, this engineering method addresses buildings in a manner similar to the probablistic risk assessment of Section 8.5

This method also addresses the consequences of fire and the extent or severity of loss, rather than ignition frequency. It can utilize loss statistics, fault tree analyses or other analyses to determine the critical events or fire scenarios. The 'critical areas procedure' of Appendix A provides a useful basis for this building firesafety application.

This method emphasizes engineering solutions for the building-fire interactions by comparing alternative designs. Like the PRA, the Engineering Method relies on subjective engineering judgement to quantify the probablistic events. This judgement often is based on relationships available in the scientific literature to evaluate the expected performance of the fire and its defenses. Confidence in the quantification often is related to the confidence in the associated fire research areas. The subjective probablistic judgements used today can be replaced in the framework by reliability analyses and deterministic equations when they are developed.

The Engineering Method for Building Firesafety has 8 major parts:-

(i) Identification of objectives
(i) Prevent established burning
(iii) Flame movement analysis
(iv) Smoke movement analysis
(v) Structural frame analysis
(vi) Life safety analysis
(vii) Property damage analysis
(viii) Continuity of operations analysis

Fire research knowledge and modelling of ignition, flame spread and heat generation is further advanced at this time than it is for smoke movement. Thus, like other fire analysis methods, the Engineering Method probably provides better estimates of the probability of damage due to flame spread compared with damage due to smoke or corrosive gases. However, while there are uncertainties in quantification, the method can be very powerful in looking at fire growth and comparing the effectiveness of various risk-reducing options.

The example of redundant switching equipment sets A and B (figure 14) will serve again as an illustration. The compartment could be modelled as one room or as two rooms separated by a useful dividing line called a 'zero strength barrier'. This is a technique used for analytical convenience to divide the room into zones in a manner that allows a consistent analysis .

At the present time, the Engineering Method describes the spread of fire as the probability of success in limiting the fire to a particular floor area within the room of origin or to any number of sequential rooms in the building. The descriptor of the expected fire behaviour is termed an L-curve, and is dependent upon :

- fuel characteristics - fire growth hazard potential (I-curve)
- automatic sprinkler suppression effectiveness (A-curve)
- fire department manual suppression effectiveness (M-curve)
- barrier effectiveness (B-curve)

An illustrative L-curve for a telephone switching room, having no sprinklers and good fire department attendance, is shown in Figure 15. The abscissa is the floor area of involvement with Switch A and Switch B identified.

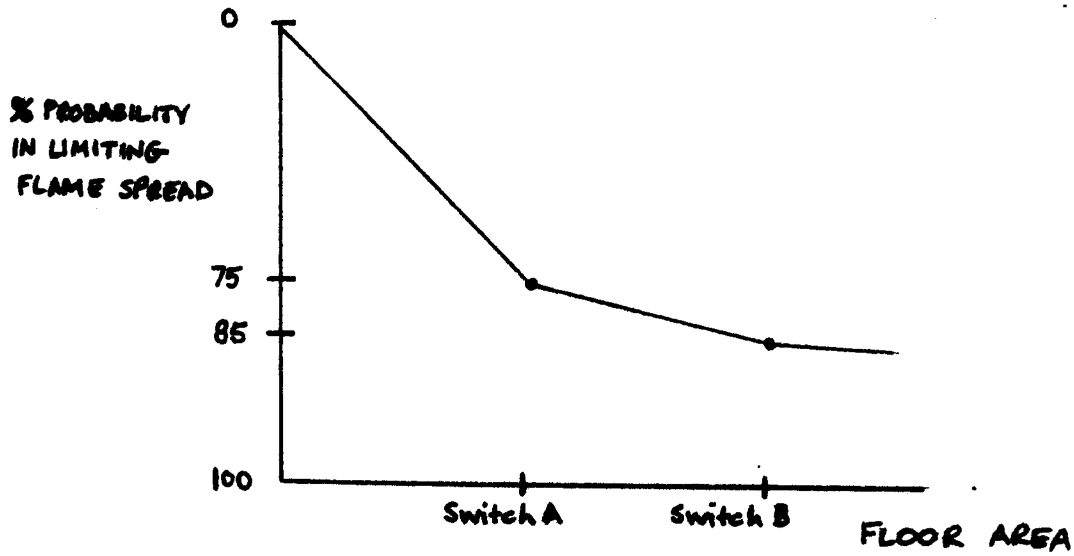


Figure 15

After the initial situation is evaluated, a series of options can be considered. These might include :

- less combustible telephone equipment materials
- a partition separating redundant switches A and B
- installation of automatic sprinklers with direct connection to fire department
- improving manual suppression response and effectiveness

The L-curves of Figure 16 illustrate how the probability of success in limiting fire spread to switch A has increased for the first three of these alternatives. When all alternatives are evaluated, they become one part of the operational and functional decision analysis process.

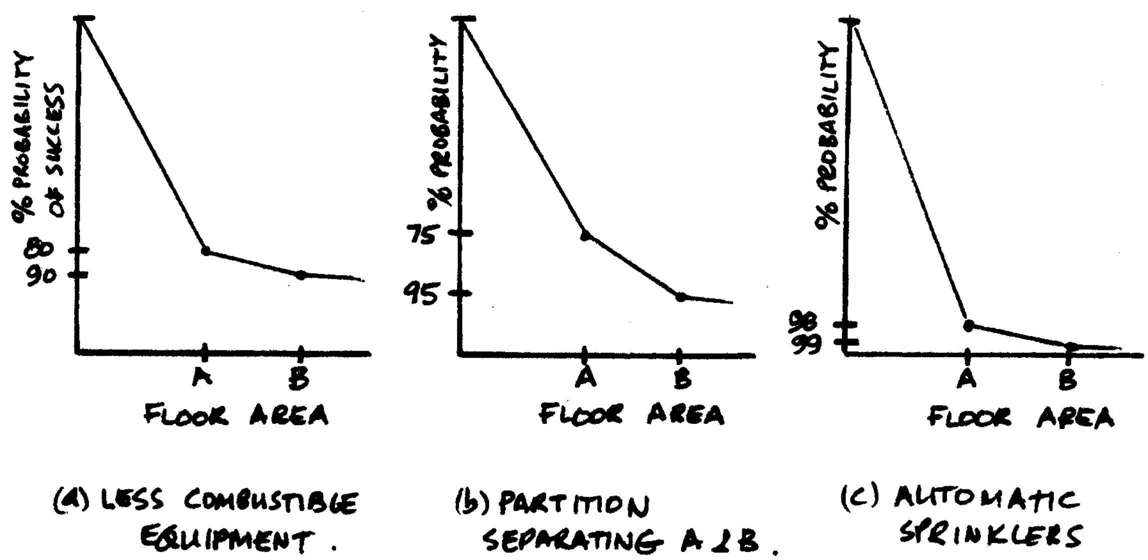


Figure 16

Often, in any business operation, fire is such a rare occurrence that fire protection deteriorates because operational attention is given to more immediate needs. Maintenance and good practices are often delayed, and eventually forgotten, until they are needed.

For example, some common deficiencies in telephone exchanges, revealed in recent inspections [54], have included:

(i) faulty fire alarm systems
(ii) combustible storage in equipment areas
(iii) open penetrations through barriers
(iv) other more hazardous equipment (e.g. batteries) not cut off from switching equipment.

L-curves can be constructed to show the reduction in safety that has evolved with time as these defiencies have developed.

Because of the sensitivity of telephone equipment to smoke and corrosive gases, an analysis based on smoke movement using the Engineering Method would also be particularly useful.

A major advantage of the Engineering Method for Building Firesafety is that it is not necessary for the engineer to have a high level of statistical or risk analysis expertise. The method provides a strong, logical and straightforward framework for analysis. This analysis can be set up to evaluate life safety, property damage or interruption to business operations, and could be applied quickly to a number of telephone exchanges at a reasonable cost.

9. CONCLUSIONS

(i) The telephone exchange is a critical part of the voice and data communication network. It may be subject to severe but very infrequent property damage and operational interruption as a result of fire or other peril.

(ii) A range of risk assessment techniques have been identified, fitted into a conceptual framework, and related to an overall risk management program for a telephone exchange.

(iii) A method for use by a consultant for systematically identifying what is at risk in a telephone exchange has been developed. This so-called Critical Areas Procedure utilizes a functionally based approach to highlight those areas of an exchange that constitute the greatest risk of property damage or interruption to business.

(iv) The critical areas procedure is partly pictorial in presentation and well suited to management decision making. It can be used to examine the risk of loss from fire as well as a number of other perils.

(v) The procedure forms the basis for examination of protection alternatives and more detailed risk assessment methods.

(vi) A number of current issues, such as the advent of the new digital switching technology, have been discussed and illustrated qualitatively using the procedure.

(vii) A range of fire incident data and loss statistics for telephone exchanges and computer facilities have been summarized.

(viii) The quantitative methods of hazard analysis, probabilistic risk assessment (PRA), and the Fitzgerald Engineering Method for Building Firesafety have been shown to be logical extensions of the critical areas procedure developed. Illustrative examples using these three methods demonstrate the quantitative approaches possible for risk assessment on telephone exchanges.

10. REFERENCES

1. The Yasuda Fire and Marine Insurance Co.Ltd., 'Fire Caused Widespread Telecom Disruption', Safety Engineering News, no 10, March 1985 p2,3.

2. Crowley, Donald P., 'Fire Risk Decision for Corporate Risk Management', M.S.Thesis, Worcester Polytechnic Institute, May 1985.

3. Pferd, W., 'A Century of Telephone Buildings', The Bell System Technical Journal, Vol.58, no.2, February 1979.

4. Rey, R.F. (Tech.Editor), Engineering and Operations of the Bell System, AT&T Labs. Inc., 2nd ed., 1982.

5. Briley, Bruce E., Introduction to Telephone Switching,Addison Wesley, Reading MA, 1983.

6. Hayward, N.S. (Ed.), 'The 5ESS Switching System', The AT&T Technical Journal, Vol 64, no.6, Part 2, July/August 1985, p1393-1447.

7. Factory Mutual Engineering Corp., Telephone Central Offices, Loss Prevention Data Sheet 5-14, 14-18, January 1985.

8. Church, F.C., Avoiding Surprises, Boston Risk Management Corporation, 1982, pp6-11.

9. VanAnne, C., Managing Risk Through Decision Analysis to Evaluate Firesafety Hazards and Extent of Probable Loss by Use of an Engineering Method., M.S.Thesis, Worcester Polytechnic Institute, 1985, pp6-13.

10. Williams, C.A. and Heins, R.M., Risk Management and Insurance, 4th Edition, McGraw Hill, New York, 1981 pp17-19.

11. DeCapua, N.J. and Simpson, J., 'Fire Risk Assessment of Large Telephone Equipment Buildings', ASTM Fire Risk Assessment Symposium, Hilton Head, June 4, 1980, p.2.

12. 'Nice Going', Worcester Evening Gazette, April 4, 1986, p.1.

13. Lees, Frank P., Loss Prevention in the Process Industries, Vols 1,2, Butterworth, London, 1980.

14. Tuler, Floyd R., 'Risk Assessment - Offshore Oil and Gas Operations', Mechanical Engineering, November 1984 p24-30.

15. Head, George L., 'Risk Management', WPI Special Seminar, November 18, 1985.

16. Kazarian, M., Siu, N.O., and Apostolakis, G., 'Fire Risk Analysis for Nuclear Power Plants : Methodological Developments and Applications'. Risk Analysis, Vol 5, no.1, 1985 pp33-51.

17. U.S.Department of Defence, 'Military Standard - Reliability Modelling and Prediction', MIL-STD-756B, 18 November 1981.

18. Lathrop, James K., 'Telephone Exchange Fire - New York, New York', Fire Journal, Vol 69, no.4, July 1975, pp5-7.

19. Fitzgerald,R., Private Communication, 1985.

20. Miller, M.J., 'Reliability of Fire Protection Systems', Loss Prevention : A CEP Technical Manual, Vol 8, 1974 (From Meeting in Philadelphia PA, Nov. 11-15, 1973), pp85-90.

21. Telecom Australia, Telecommunications Equipment Accomodation Manual, TPH1243, Melbourne, August 1984.

22. Factory Mutual Engineering Corporation, 'Programming for Computer Protection', Norwood, 1978.

23. Oleson, S.T., Effects of Corrosive Smoke on Electronics, Elektronikcentralen, ECR-145, Horsholm, 19 March 1984.

24. Braun, Emil, Review of Literature, Applicable Test Methods, and Incident Data for the Evaluation of the Fire Performance of Central Telephone Office Equipment, NBSIR 81-2261, NBS Center for Fire Research, Washington, May 1981, p18-29.

25. Crnkovich, John J., 'The Best Time to Fight a Fire is Before it Starts...',Telephony, December 6 1982 p82-90.

26. Blain, Ray, 'It's Time for Telcos to Stop Side-stepping Fire Protection', Telephony, March 31, 1975.

27.Specter, Michael, 'Burst Pipe Silences Phones in Alexandria', Washington Post, October 9, 1985.

28. Sielert, Vern, Private Communication, February 12, 1986.

29. Telecom Australia, Fire Losses 1978 - 1980, 1981-1982, 2 Vols, Melbourne, 1983.

30. Eckler, A.R., 'A Statistical Analysis of Bell System Building Fires, 1971-1977', The Bell System Technical Journal, Vol 57, no.8, October 1978, pp2769-2796.

31. Krasner, L.M. and Wiener, S.A., 'The Feasibility of Quantitatively Analyzing Investments in Loss Prevention Activities', Factory Mutual Research Report FMRC 19257, April 1973, pp14-15.

32. Rutstein, R., 'The Estimation of the Fire Hazard in Different Occupancies', Fire Surveyor, Vol 8, no.2, April 1979, p21-25.

33. Hession, V.,'Fire Protection : a Burning Issue for Telecos', Telephony, March 14, 1983 p22-23.

34. Sielert, Vern A., 'Modern Fire Protection : an Application', Telephony, July 15, 1974.

35. Johnson, P.F., 'Loss Expectations With Computer Equipment', WPI FP-552, Worcester, May 1985.

36. Bissell, W., Chutoransky, R., and Crowley, D., 'Computer Room - Fire Risk Evaluation', WPI FP-552, Worcester, May 1981.

37. Snelling, J.W., 'Fire Protection, Prevention, Security Control Measures Against Preventative Loss', John W.Snelling and Associates, Melbourne, November 1985.

38. Wuthrich, M., 'Fire in Zurich - Hottingen Telephone Exchange -Chemical Problems', Technische Mitteilungen PTT no.12, 1970, pp536-547.

39. Rifa Tapia, E., 'Fire in a Telephone Exchange Building in Barcelona', Barcelona Fire Department, June 1973.

40. Bi-monthly Fire Record, 'Telephone Substation, Hawaii, May 16', Fire Journal, Vol 76, no.5, September, 1982, p48

41. Moghissi, A.Alan, 'Risk Management - Practice and Prospects' Mechanical Engineering, November 1984, p21-23.

42. Simmons, R.F. and Tyler, B.J., 'Hazard Assessment Techniques Used in the Chemical Industry and Their Possible Uses Elsewhere', Fire and Materials, Vol 8, no.4, 1984, pp199-205.

43. Concawe's Risk Assessment Ad-Hoc Group, 'Methodologies for Hazard Analysis the the Petroleum Refining and Storage Industry : Appendix III - Analytical Procedures', Hazard Prevention, Vol 19, no.6, November/December 1983, pp16-32.

44. Dow Process Safety Guides, CEP Reprint, American Institute of Chemical Engineers, 1966.

45. Course Manual, Fire and Explosion Protection, UMIST, 1980.

46. National Fire Protection Association, Life Safety Code, 1985 Edition, NFPA, Quincy, February, 1985.

47. Fire Safety Evaluation (Points) Scheme for Patient Areas Within Hospitals, Department of Fire Safety Engineering, University of Edinburgh, June 1982.

48. Hazard and Operability Studies, Chemical Industries Association Ltd., 1977.

49. Hasegawa, H.K. and Lambert, H.E., 'Reliability Study on the Lawrence Livermore National Laboratory Water Supply System', First International Symposium on Fire Safety Science, Gaithersburg, October 9-11, 1985.

50. Allen D.J. and Rao M.S.M., 'New Algorithms for the Synthesis and Analysis of Fault Trees', I&EC Fundamentals, Vol 19, February 1980, p.79.

51. Kazarians M., Siu N. and Apostolakis G., 'Risk Management Application of Fire Risk Analysis', First International Symposium on Fire Safety Science, Gaithersburg, October 9-11, 1985.

52. Fitzgerald, Robert W. and Wilson, Rexford, Building Firesafety Evaluation : A Workbook, Worcester Polytechnic Institute, 1983.

53. Nelson H., Building Firesafety Criteria, Appendix D : Interim Guide for Goal Oriented Systems Approach to Building Firesafety, General Services Administration, Washington, D.C., 1972.

54. Van Anne C., Private Communication, 1986.

APPENDIX A

PROCEDURE FOR IDENTIFYING CRITICAL AREAS IN A CENTRAL OFFICE TELEPHONE EXCHANGE

P.F.JOHNSON

WORCESTER POLYTECHNIC INSTITUTE
CENTER FOR FIRE SAFETY STUDIES

Procedure for identifying critical areas in a central office telephone exchange

Introduction

This procedure is one that would be used by a consultant engineer or risk analyst in examining the risk of property damage or interruption to business of a telephone exchange due to any peril such as flood, fire, electrical interference, etc.

The use of any risk assessment technique requires that the system under examination, in this case a central office telephone exchange, be well understood functionally so that the risks of all potential losses can be clearly identified.

This procedure, then, is designed to help in identification of areas of an exchange that are critical to the system meeting its stated property damage and business interruption objectives.These objectives, for the exchange under consideration, should be set as part of the overall risk management plan for the telephone organization. They should be stated in terms of limits on property damage and business interruption losses that could be sustained without significant operational or financial hardship..

Considerable information must be gathered on the functional operation of the telephone exchange in order to complete this procedure. Much of the information will have to come from the telephone company involved, but in all cases it should be supplemented by information collected by the consultant/risk analyst during actual site visits. The visits are highly desirable because telephone buildings are continually being modified in both structure and services to take account of the new generations of electronic equipment being introduced.

Once the information has been gathered, the procedure calls for the preparation of the following drawings:-

- telephone equipment schematic
- services equipment schematic
- building floor plans
- sectional views

These drawings of the functional and physical relationships will provide a systematic basis for the identification and valuation of telephone and services equipment assets in an exchange. They will also enable the impact of the loss of a section of equipment to be studied in respect of business interruption losses. A survey form, based on the schematics, is provided. The form is a ready means of checking and identifying equipment areas critical to the property damage and business interruption objectives.

The use of schematics and building drawings required in this critical areas procedure could be prepared by conventional drafting methods. However, the use of computer aided design

(CAD) techniques would greatly facilitate later drawings required by the procedure. These drawings overlay the functional schematics with highlighted equipment areas that are critical if property damage and business interruption losses are to be minimized.

1. Telephone equipment schematic

1.1 Construct a block diagram of the telephone equipment (not services equipment) to show in schematic form all major equipment items and their functional relationships. The schematic should avoid great detail - see sample diagram attached (Figure 1).

The following general blocks found in telephone exchanges should be used:-

- cable entrance facility
- signal mixing/multiplexing equipment (if applicable)
- main distribution frame
- switching equipment
- controlling computer & memory (if applicable)
- billing equipment (if separate from switching equip.)

1.2 All equipment parts in a single building space that are interdependent and required to function for continued operation of that section of the exchange should be shown as a single functional block on the schematic. For example, when considering switching equipment, the switches, markers, in/out links, tone generators. etc should be shown as one block PROVIDED that they are all located within the same physical compartment.

1.3 Associated equipment that is located in another physical compartment (defined by the structural fire barriers), or redundant equipment of the same type regardless of its location should be shown as a separate functional block.

1.4 Telephone equipment that is dependent upon other telephone equipment in another physical space should be shown in 'SERIES' in the schematic.

1.5 Redundant equipment should be shown in 'PARALLEL' in the schematic.

1.6 Do not include in the schematic any non-functional rooms/spaces in the exchange such as stairways, offices, kitchens, control rooms, unless they are essential to the uninterrupted operation of the exchange.

1.7 Where they exist, spare equipment frames, spare parts, components etc. that are considered essential to rapid replacement of failed sections of equipment on a regular basis should be shown as a separate functional block. This should apply whether or not they are stored in a separate compartment from the operational equipment they could be used to replace. The objective is to see whether the equipment and its replacement could be simultaneously damaged by a single loss incident.

1.8 Each functional block of the schematic should be shown in a separate diagrammatic 'compartment' for analytical purposes, even though it might not be physically separated from surrounding equipment. For example, two separate redundant sections of switching equipment should be shown in separate diagrammatic 'compartments' even though physically they may be in the same actual building compartment in the telephone exchange.

1.9 Each equipment block should be identified with a building floor number and room or compartment number. (e.g. F23/C17) If the building has no room numbering system, then one should be designed for the purpose so that equipment locations are clearly and unambiguously stated.

1.10 Individual blocks should now be linked by lines indicating the telephone cable connections between blocks. This is only a functional representation, and separate lines for pairs of cables having different paths between the two blocks of equipment is not required in this schematic.

1.11 Services provided as inputs into each space for the equipment contained therein should be shown on this schematic simply as a symbol and short line attaching it to the block . This is done to facilitate the later identification of the piece of service equipment that is serving as the source of power, chilled water, etc (see Section 2 - services schematic).

The color-coded symbols suggested for use are:-

110 (red)		mains power (single and three phase)
50 (red)		50 VDC power (for telephone equipment)
W (blue)		water (mains/chilled - for HVAC/cooling)
S (blue)		steam (for heating)
A (green)		HVAC conditioned air
F (black)		fuel (gas/oil - for HVAC or standby power)

1.12 To give some preliminary idea of the strength of the physical barriers between the functional equipment blocks, mark the nearest equivalent type of barrier on the schematic 'compartment' boundary using the following limited symbols:-

OB	- no barrier	(zero strength)
WB	- weak barrier	(e.g. glass partition)
MB	- moderate barrier	(e.g. plaster/stud partition)
SB	- strong barrier	(e.g.reinforced concrete wall or floor/ceiling assembly)

Where a barrier has significant areas such as doors or other lightweight panels that will reduce its fire resistance, then the barrier strength should be downgraded to the more appropriate type. Where a barrier has only small holes or penetrations that could be fixed to restore the nominal fire resistance, then do not downgrade it.

2. Building services schematic

2.1 Construct a second schematic of the building services to show their functional relationship - their physical relationship and service connections will be shown on later plan and sectional views.

Again the color-coded symbols to be used as outputs are:-

110	(red)	mains power
50	(red)	50 VDC power
W	(blue)	water (mains/chilled)
S	(blue)	steam
A	(green)	HVAC conditioned air
F	(black)	fuel (gas/oil)

2.2 As before, each piece of equipment should be shown as a separate block in a separate diagrammatic 'compartment' even though in some cases the barriers will be of 'zero strength' (see sample services schematic attached - Figure 2).

2.3 Again parts of a services subsystem located in different building spaces should be linked together in 'SERIES' and redundant equipment shown in 'PARALLEL'.

2.4 All services blocks should be identified with their floor number and room/compartment number (e.g. F7/C34).

2.5 All services equipment blocks should be linked with color-coded lines to indicate flow of power, air, water, etc. Arrows should be put on the lines to indicate the direction of flow where appropriate.

2.6 Ratings of physical barriers should again be noted on the diagrammatic boundaries around blocks by choosing the nearest equivalent barrier. Symbol choice, as before, is:-

(OB)	- no barrier	(zero strength)
(WB)	- weak barrier	(e.g. glass partition)
(MB)	- moderate barrier	(e.g. plaster/stud partition)
(SB)	- strong barrier	(e.g. reinforced concrete)

2.7 Check each color-coded service INPUT on the telephone equipment schematic with the appropriate service OUTPUT on the services schematic to clearly identify the functional relationship between the two schematics.

3. Floor Plans and Sectional Views

3.1 A series of drawings should be prepared to illustrate the physical relationships between telephone and services equipment so that the full impact on telephone exchange operations of damage in one area can be assessed. This will provide a basis for assessment of business interruption potential.

3.2 The series of drawings should consist of a floor plan for each floor of the building together with one or more sectional views (or isometric 3Ds) as is considered necessary. A typical sectional view is shown as Figure 2 attached. Some simplified building plans showing telephone and services equipment, if available, may be used for this purpose provided they are fully up to date.

3.3 The drawings should show all functional telephone and services equipment blocks illustrated on the schematics. The blocks should be clearly labelled both in the plan and sectional views with their appropriate floor and compartment number.

3.4 Also shown should be all interconnections including both telephone signal cables and services equipment, such as power cables, HVAC ducts, etc. These should be appropriately color-coded and labelled as in other drawings.

3.5 Of major importance to illustrate on these drawings are the areas such as common ducts, cableways, shafts etc. where multiple services or redundant cables run close together and where an incident could damage a number of systems simultaneously.

3.6 Given the complexity of a telephone exchange, a large number of cables, ducts, etc. may appear too complicated on one drawing set. Therefore, some simplification only to show cables, etc sufficient to demonstrate the physical inter-relationships and the potential common losses is justified. Alternatively, consideration may be given to using transparent overlays or CAD generated drawings with each type of services placed on a separate sheet. However, if this latter approach is taken, it is essential that consistency be maintained so that the physical relationships between different equipment interconnections can be seen clearly.

4. <u>Property damage</u>

4.1 In order to identify telephone and services equipment that is in excess of a property damage (P.D.) objective (e.g. a $1.0 million insurance deductible), a systematic approach should be employed using the functional schematics. The assistance of the telephone company is important in this step to ensure accurate valuations.

4.2 A list of all telephone and services equipment blocks identified on the schematics (sections 1,2) should be prepared first . This might consist of a survey form similar to the sample provided as Figure 3 attached at the end of this procedure.

4.3 The list should include any non-functional areas or compartments containing equipment not essential to the continuing operation, but which, if destroyed, would constitute a substantial P.D. loss. For example, alarm/control areas, specialist maintenance facilities, operator services would be in this category.

4.4 The listing should be consistent with the schematics and should show all equipment areas identified by floor and compartment numbers. Equipment replacement cost and the best possible estimate of supply/repair and installation times should be provided. More sophisticated analyses might utilize the most optimistic, most pessimistic and most likely estimates of these costs and times.

4.5 Once the listing is completed, all those telephone, service and other equipment areas that exceed the property damage objective should be highlighted by coloring, hatching or some other method on the schematics (sections 1,2) and on the floor plans and sectional views (section 3).

This should clearly reveal to the client:-

- the extent and concentrations of high value equipment
- existing horizontal and vertical separation between valuable equipment areas

and provide a focus for property damage risk assessments.

4.6 The highlighting of 4.5 above could be carried out using a plastic overlay technique. However, modern CAD methods provide the easiest approach to simply filling in the telephone and services equipment blocks with colour or hatching for prominence.

5. Business interruption

5.1 To provide a basis for assessment of business interruption potential, a systematic approach similar to that taken for property damage should be made. Again assistance of personnel from the telephone company should be sought in analyzing the implications of various equipment failures on business interruption.

5.2 Given an already decided telephone company objective for business interruption (e.g. no loss to exceed 3 days nor more than 500 lines; or no revenue loss to exceed $2.0 million), all telephone and services equipment areas essential to that objective should be identified on that survey form (Figure 3).

5.3 Where a number of sets of redundant equipment exists, such as switches, that are not all required to operate simultaneously, identify as essential only that number of sets required to meet the stated B.I. objective. For example, three sets of switching equipment out of an available five may be considered essential to meet the peak demand.

5.4 Once the survey form or similar listing has been completed, highlight on the schematics, floor plans and sectional views, all equipment areas identified as essential to meeting the B.I. objective. Again this could be achieved by colour, hatching, or some other appropriate means

The areas could be ESSENTIAL either because their loss would:-

- immediately exceed the number of lines limit (e.g. total loss of cable vault)
- cause the no. lines limit to be exceeded after a time less than the maximum interruption period. (e.g. loss of chillers might lead to shutdown of operations 3 hours after failure.)
- exceed the maximum interruption period (loss of equipment with long replacement period)
- exceed a revenue loss limit (e.g. damage to billing or records equipment)

5.5 This highlighting of equipment blocks essential to the B.I. objective of the client could again be achieved by a plastic overlay or CAD technique.

5.6 Also critical to continuity of operations, but not easily included on the survey form are those areas where telephone cables and services interconnections run in common ducts, cableways, shafts, etc. In these areas, a small, seemingly insignificant loss to say the main power cable or common chilled water supply main for the building may perhaps result in a major B.I. loss. These areas should be highlighted on the floor plans and sectional views as well.

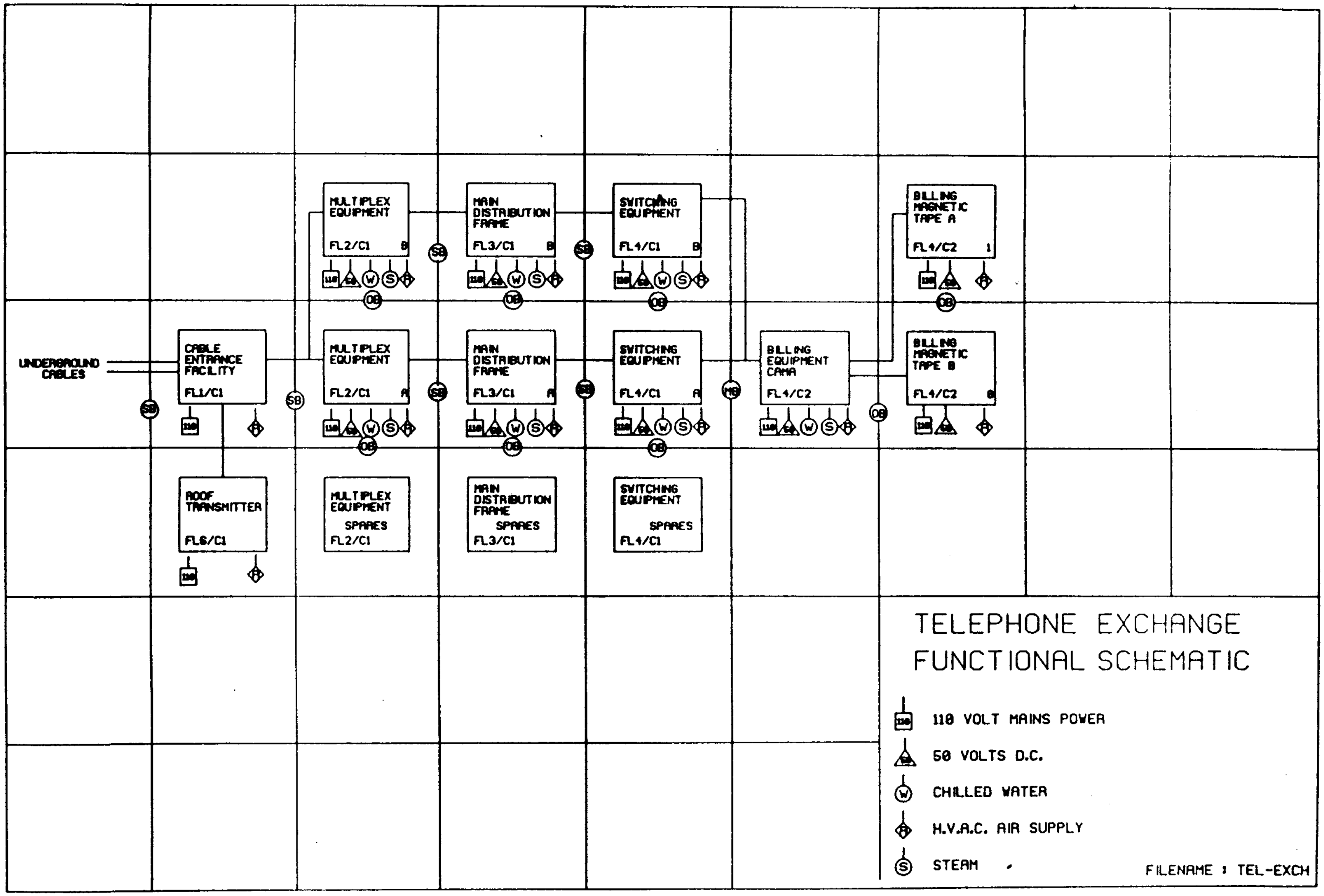
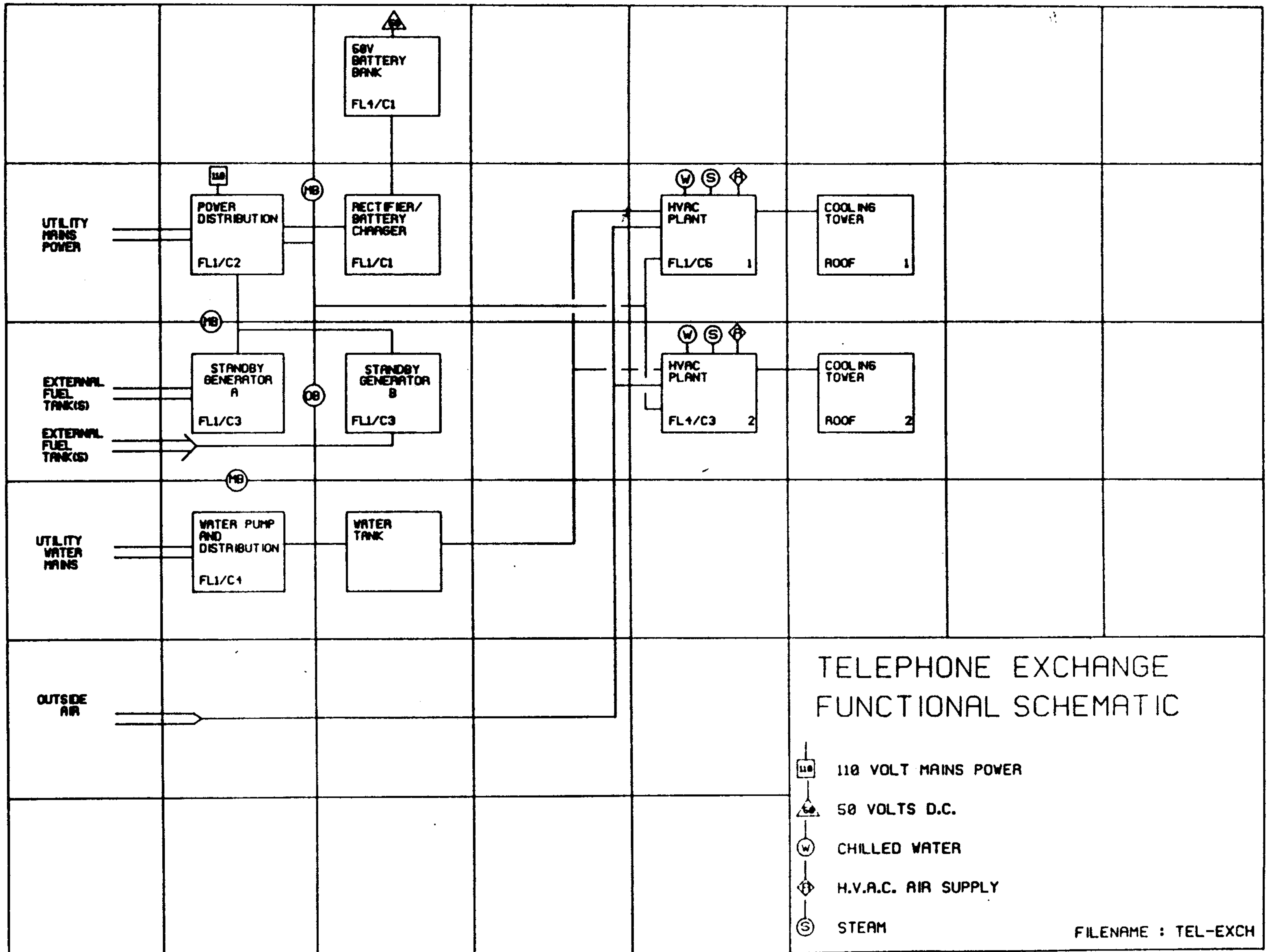


FIGURE 2-TELEPHONE EQUIPMENT



TELEPHONE EXCHANGE FUNCTIONAL SCHEMATIC

FILENAME : TEL-EXCH

FIGURE 3-SERVICES EQUIPMENT

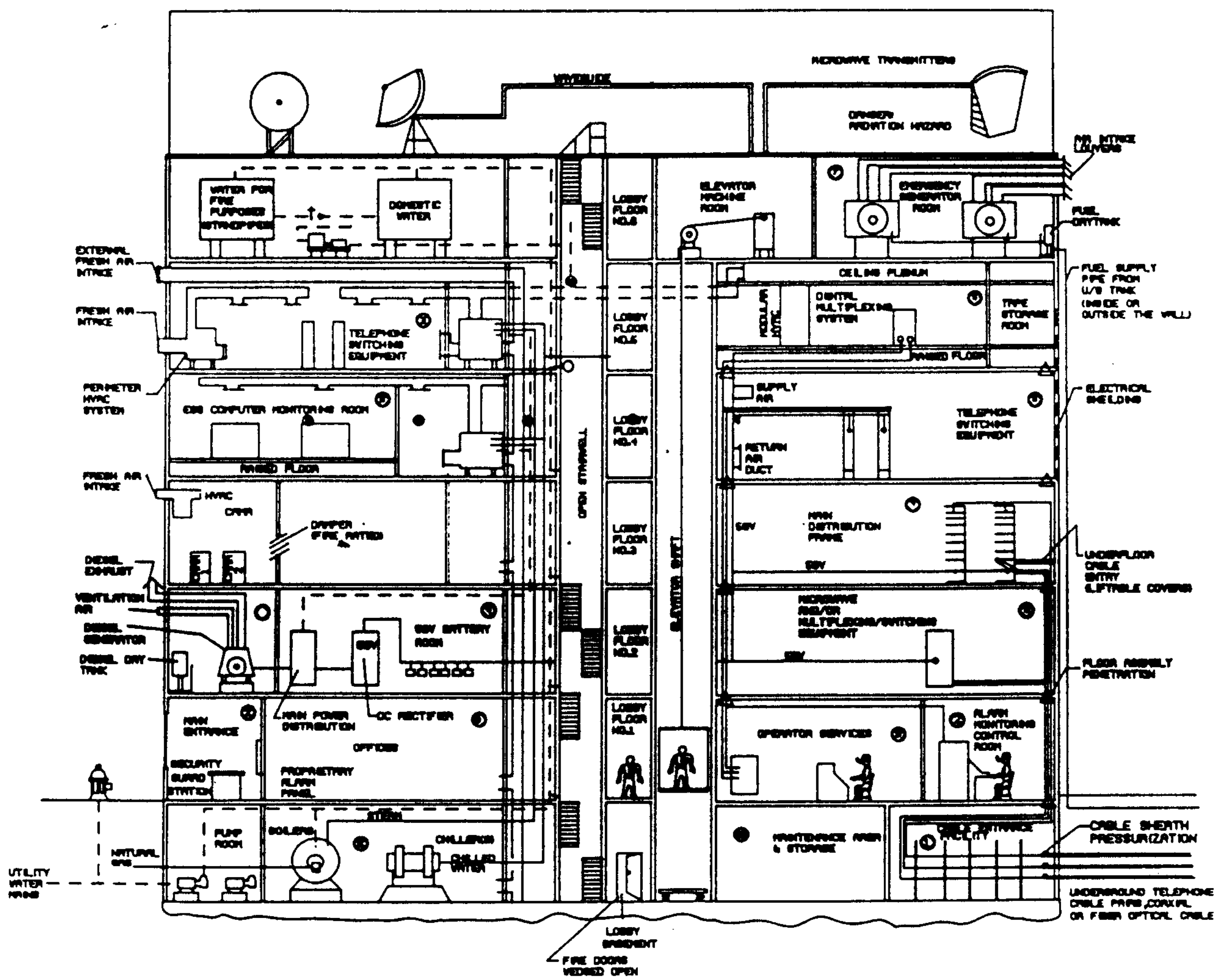


FIGURE 4-SECTIONAL VIEW OF TELEPHONE EXCHANGE

CENTRAL OFFICE TELEPHONE EXCHANGE
PROPERTY DAMAGE/BUSINESS INTERRUPTION
SURVEY FORM

1.Record all equipment types, locations and relevant costs as per the CRITICAL AREAS PROCEDURE.
2.Costs should be given in multiples of thousands or millions of dollars appropriate to the size of the exchange.
3.Attach additional sheets as required.

Equipmnt Type	Floor No.	Compart No.	Replacmt Cost ($)	Sply/Repr Time(d/h)	Install Time (dy/hr)	Essential to B.I. (yes/no)
TELEPHONE Cable (1) Vault (2)						
Multi (1) Plex (2) (3) (4)						
Distrb(1) Frame (2) (3)						
Switch(1) (2) (3) (4) (5)						
Billng(1) Equip (2) (3)						
Com- (1) puters(2) (3)						
Micro-(1) wave (2) Equip (3) (4)						

Equipmnt Type	Floor No.	Compart No.	Replacmt Cost ($)	Sply/Repr Time(d/h)	Install Time (dy/hr)	Essential to B.I. (yes/no)
SERVICES Power (1) Distrb(2) (3) (4)						
Stndby(1) Power (2) (3)						
Rectif(1) Battry(2) (3) (4)						
Boiler(1) (2)						
Chillr(1) (2)						
Coolng(1) Tower (2)						
Fan (1) Rooms (2) (3) (4)						
Pump (1) Rooms (2)						
OTHER Opertr(1) Servcs(2) Contrl(1) Rooms (2) (3) Maintn(1) Facilt(2)						