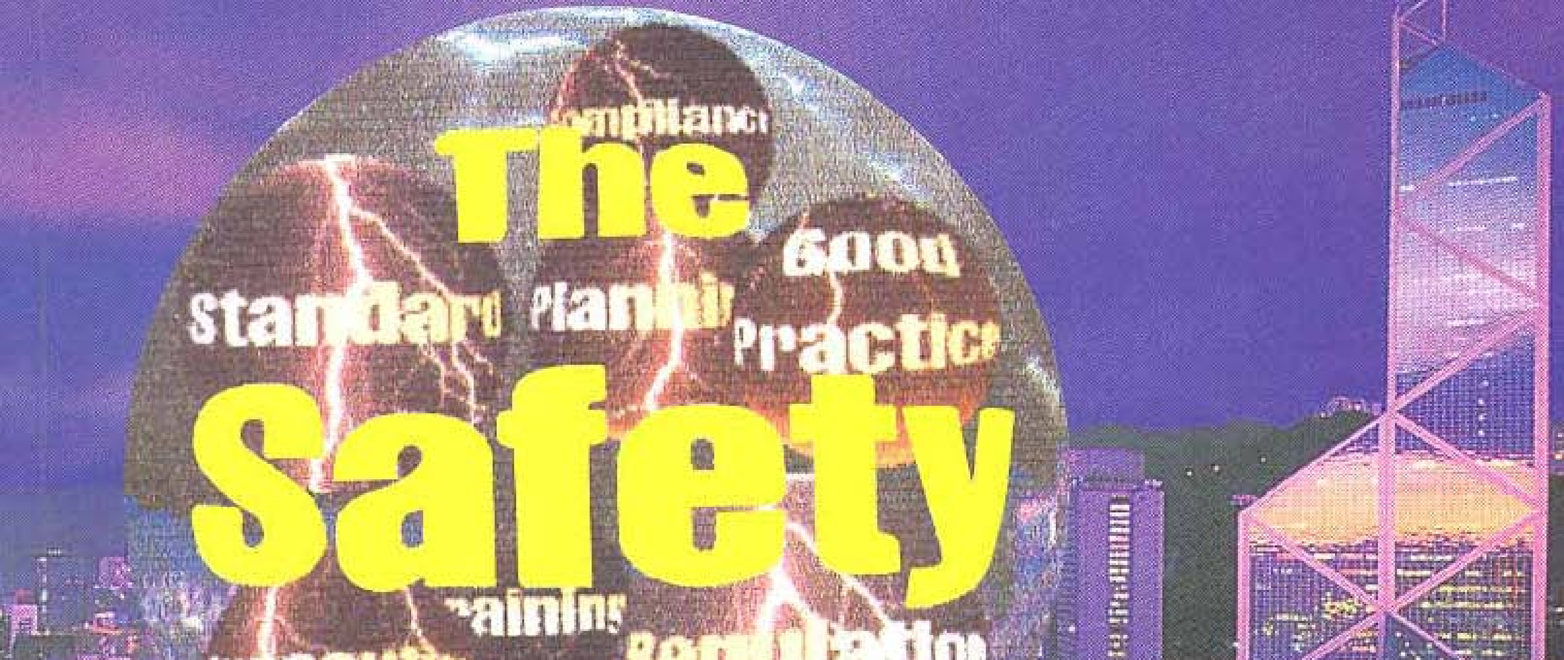
# The Tenth Annual Symposium

**Thursday 22nd October, 1992**




THE HONG KONG INSTITUTION OF ENGINEERS

ELECTRICAL DIVISION

# THE HONG KONG
# INSTITUTION OF ENGINEERS
# ELECTRICAL DIVISION

***The Tenth Annual Symposium***

Thursday

22nd October 1992

## *THE SAFETY IMPERATIVE*

at

Silver Ballroom,

Sheraton Hotel,

Nathan Road,

Kowloon.

# MESSAGES

## Message from Professor P.J. Lawrenson IEE President

This conference comes at a time when the ever-increasing use of advanced technology to create highly complex and potentially dangerous systems is combined with much greater public awareness of the need for safety. Worldwide this public interest is resulting in growing legislation to protect both people at work using manufacturing systems and the consumers who purchase and use the products of those systems.

As designers and creators of systems, engineers have a major role to play in ensuring that a truly professional attitude is adopted towards safety and quality. Everyone throughout the profession must be involved. Consultants, practitioners and managers at all levels have responsibility not only for what they do themselves, but also what they permit others to do, or not to do.

To fulfil their responsibilities, engineers must keep themselves up-to-date and learn from the experience of others. The conference organisers are to be congratulate on the opportunity they have provided for obtaining a rounded view of current thinking on safety matters and quality standards.

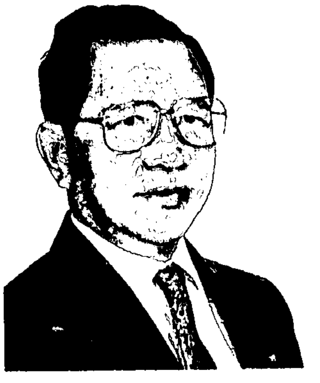
I feel sure that all those taking part in the Symposium will benefit greatly. I send you my best wishes for a very successful event.

Peter Lawrenson

Professor P.J. Lawrenson
President
IEE

# MESSAGES

**Message from Mr. Kwok Ping-ki, JP**
**Director**
**Electrical & Mechanical Services Dept**



I am extremely pleased to see this annual event organised by the Electrical Division of The Hong Kong Institution of Engineers has entered its 10th Anniversary, with a different theme each year to suit the current interest in the electrical engineering profession.

I am particularly pleased to see that Safety Imperative has been chosen as the theme of this year and I must congratulate the Organising Committee for their efforts in selecting the most relevant topics for delivery by the most notable speakers.

I am sure all participants will be able to benefit from the Symposium and bring home the important message of Safety not only to the organisations from where they come but also to the general public with whom they work.

I wish the Electrical Division every success in the Symposium.

Kwok Ping-ki
Director
Electrical & Mechanical Services Department

# MESSAGES

**Message from Sir William Stones**
**Managing Director**
**China Light & Power Co. Ltd.**

The Hong Kong Institution of Engineers has a history of over 45 years and has grown to become one of the most respected professional bodies in Hong Kong. The Annual Symposium organised by its Electrical Division provides an important venue for electrical engineers to gather and exchange technical information and ideas to the benefit of the profession.

Electricity is continuing to grow in importance as a source of power for industry, for transport and communications, and for domestic use. The ways in which electricity is being harnessed today from a great variety of energy sources pays tribute to the advances made in the field of electrical engineering.

In the effective supply and use of electricity, engineers are constantly being encouraged to aim for higher standards and improved efficiency. It is pleasing, therefore, to see that "Quality" has been selected as one of the themes for this year's Symposium. Without a high quality supply of electricity - reliable, safe and economical, it would not be possible for Hong Kong nor any other country to enjoy an ever growing prosperity and a continuous improvement in the quality of life.

I congratulated the Electrical Division of the HKIE on organising its Tenth Annual Symposium this year and I look forward to the continuing success of this valuable symposium programme.

Sir William Stones
Managing Director
China Light & Power Co. Ltd.

# MESSAGES

**Message from Mr. Ewan Yee**
**Managing Director**
**The Hongkong Electric Co., Ltd.**

On the occasion of the Tenth Anniversary of the Symposium organised by the Hong Kong Institution of Engineers - Electrical Division, I would like to congratulate those who have been and are involved in the organising of this annual event.

The Symposium provides an invaluable opportunity for the electrical engineering profession to meet annually to exchange views and update themselves on the latest developments and happenings in the electrical engineering and related fields.

I wish the Institution every success in all its ventures.

Ewan Yee
Managing Director
The Hongkong Electric Co., Ltd.

# MESSAGES

## Message from Dr. R.M. Kennard
## President
## Hong Kong Institution of Engineers

As President of the Hong Kong Institution of Engineers I am delighted to congratulate the Electrical Division on the occasion of their 10th Annual Symposium. Over those past 10 years I have personally noted the success of the annual symposium. Even though the very first symposium was of the very highest technical quality it seems that the Electrical Division has, through its high calibre input and attention to detail, improved upon the unimprovable. I am certain that this year's symposium will be most stimulating and I look forward to participating.

I reiterate my congratulations.

R.M. Kennard
President
Hong Kong Institution of Engineers

# SYMPOSIUM PROGRAMME

**08:30** **Registration and Coffee**

**09.00** **Welcome Address**

- Mr. Otto L.T. Poon
  FHKIE, CEng., FIEE, FIMechE, MCIBSE, MIWEM
  Chairman, Electrical Division, HKIE

**09.05** **Opening Address**

- Dr. R.M. Kennard
  FHKIE, CEng., FICE
  President, HKIE

**09.10** **Keynote Speech**

- Mrs. Elizabeth M. Bosher
  Acting Secretary for Economic Services

## 1. *Regulations*

**09.40** **The Approach on Electrical Products (Safety) Regulations**

- Mr. John Chan/Mr. T.H. Tai
  Chief E&M Engineer/Senior E&M Engineer
  Electrical and Mechanical Services Department

**10.00** **IEE Wiring Regulations - Evolution from 14th to 16th Edition**

- Mr. William Chan
  Committee Member
  Hong Kong Electrical Contractors' Association

**10.20** **Discussion**

**10.45** **Coffee Break**

## 2. *Supplies/Products*

**11.15** **Safety Considerations for the Design, Construction and Operation of Cable Tunnels**

- Mr. C.T. Wan/Mr. K.T. Hong
  Chief Electrical Engineer/Senior Electrical Engineer
  The Hongkong Electric Company Ltd.

**11.35** **Measuring Safety Pro-actively**

- Mr. Russell Powell
  Five Star Safety & Health Management Programme Consultant
  China Light & Power Company Ltd.

| | |
|---|---|
| 11.55 | **The Role and Development of Protection in the Safe Operation of Power Supply Systems**<br>- Mr. N.F. Chin<br>Export Sales Manager<br>GEC ALSTHOM Protection & Control Ltd. |
| 12.15 | **Discussion** |
| 12.30 | **Lunch** |

## 3. *Impact to Society*

| | |
|---|---|
| 14.15 | **Society's Expectations for Safety - Can They be Met?**<br>- Mr. Trevor Adams<br>Safety Services Manager<br>Mass Transit Railway Corporation |
| 14.35 | **Nuclear Power and its Implications on Public Safety in Hong Kong**<br>- Dr. Raymond Yeung<br>Lecturer<br>Department of Mechanical Engineering<br>University of Hong Kong |
| 14.55 | **Discussion** |
| 15.10 | **Coffee Break** |
| 15.30 | **Electrical Fire Safety to Protection**<br>- Mr. Richard Lo<br>Deputy Chief Fire Officer (Protection)<br>Fire Services Department |
| 15.50 | **Electrically Sick Buildings - Symptoms, Diagnosis & Treatment**<br>- Mr. W.H. Wong<br>Director<br>BMP Mechanical & Electrical Ltd. |
| 16.10 | **Discussion** |
| 16.30 | **Summing Up**<br>- Symposium Chairman<br>Mr. P.H. Ho<br>Electrical & Mechanical Services Department<br><br>**Closing Address**<br>- Hon. Dr. Samuel P.W. Wong, MBE, JP<br>FHKIE, FEng., FICE, FIEE, FCIBSE, FIMechE, FIProdE, LLD<br>HKIE's Legislative Councillor |

## Acknowledgement

The Electrical Division of The Hong Kong Institution of Engineers would like to express its sincere appreciation and gratitude to the following persons and organizations for their contributions to the Symposium:

### Speakers/Authors

Dr. R.M. Kennard
Hon. Mrs. Anson Chan
Mrs. Elizabeth M. Bosher
John Chan
T.H. Tai
William Chan
C.T. Wan
K.T. Hong
Russell Powell
N.F. Chin
Trevor Adams
Dr. Raymond Yeung
Richard Lo
W.H. Wong
Hon Dr. Samuel P.W. Wong

### Sponsors

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Ryoden Engineering Co. Ltd.
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Greenland Engineering Co. Ltd.
Wai Wah Engineering Co.
Tridant Engineering Co. Ltd.
Wah Tung Engineering Co. Ltd.
Shell Electric Manufacture Holdings Co. Ltd.
Dah Chong Hong (Engineering) Ltd.
Hong Kong & Kowloon Electric Trade Association
Hong Kong Electrical Contractors' Association Ltd.

*Cover Design Idea of this Booklet by Mr. Alex Cheong, CANATAL International Inc.*

## 10TH SYMPOSIUM ORGANIZING COMMITTEE

| | |
|---|---|
| Symposium Chairman: | Mr. P.H. Ho |
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| | Mr. Peter Y.S. Wong |
| | Mr. David Yuen |
| | Mr. S.S. Yuen |
| | Mr. W.H. Wong |
| | Mr. Edward Yeung |
| | Mr. T.H. Tai |
| | Mr. C.L. Wong |
| Hon. Secretary and Treasurer: | Mr. Y.K. Chu |

Paper No. 1

# THE APPROACH ON THE ELECTRICAL PRODUCT (SAFETY) REGULATIONS

Speakers : Mr. John Chan
Chief Electrical & Mechanical Engineer
and
Mr. T.H. Tai
Senior Electrical & Mechanical Engineer
Electrical & Mechanical Services Dept
Hong Kong Government.

# THE APPROACH ON THE ELECTRICAL PRODUCT (SAFETY) REGULATIONS

Mr. John Chan

Chief Electrical & Mechanical Engineer

Mr. T.H. Tai

Senior Electrical & Mechanical Engineer

Electrical & Mechanical Services Department
Hong Kong Government

Pap
No.

## SYNOPSIS

In this paper, the approach adopted by Electrical & Mechanical Services Department of the Hong Kong Government on the proposed Electrical Products (Safety) Regulations will be explained. It includes the purpose, application, concept of essential safety requirements, classification of prescribed and non-prescribed products and the responsibilities of various parties under the proposed Regulations.

## 1. INTRODUCTION

The Electricity Ordinance (Cap. 406) was introduced in 1990 to replace the old Electricity Supply Ordinance (Cap. 103) as a measure to improve the safety of electricity usage. Among the five main Regulations, the Electricity (Registration) Regulations call for registration of electrical workers and contractors while the Electricity (Wiring) Regulations govern the safety requirements, including both the quality of material and workmanship for FIXED electrical installations. These together with the Electricity (Exemption) Regulations provide the legislative framework for the safety of fixed electrical installations of domestic, commercial and industrial consumers. The proposed new Electricity Supply Regulation will focus on the installations of electricity suppliers. The safety requirements of domestic electrical products will be governed by the proposed Electrical Products (Safety) Regulations (EPSR). The objective of the Regulations is to protect the public from physical injuries and damages caused by the use of unsafe electrical products.

## 2. PURPOSE OF THE EPSR

The proposed Electrical Product (Safety) Regulations are designed for enhancing safety in the use of electrical products with the following objectives :-

a) introducing safety requirements for locally used electrical products;

b) ensuring close adherence to the prescribed safety requirements of the products; and

c) prohibiting the sale, hire or use of any product which fails to comply with the safety requirements.

To meet this end, the Regulations will specify :

i) the general safety requirements for electrical appliances and specific requirements for certain types of electrical products. Electrical products which fail to meet the safety requirements of the Regulations will be prohibited under the Electricity Ordinance for sale, hire or use; and

ii) the responsibilities and duties of the concerned parties including the manufacturers, importers, certification bodies, consumers and the Director of Electrical & Mechanical Services (hereinafter known as the Director).

## 3. APPLICATION

The Regulations will apply to electrical products that are :-

a) either imported or manufactured locally;

b) for local sale, hire or use; and

c) designed or suitable for domestic use.

The Regulations apply only to electrical products for domestic use because electrical products for industrial use may be so specialized that the safety requirements stipulated in the Regulations cannot be wholly applied.

## 4. DEVELOPMENT OF THE DRAFTING WORK

A total of 24 Government departments and private organizations were consulted regarding the principles of the Regulations in 1987. The drafting work then began. There have been many modifications along the way to take account of international developments in certification and standards. Moreover, the introduction of Toys and Children's Products Safety Bill in early 1992 also provoked some enlightenments to the proposed Regulations, especially when we take account of the comments from different organizations in the community. We are also aware of the changes of national regulatory approaches of other countries, the latest world trend in ISO 9000 for quality assurance of the manufacturers and the mutual recognition of accreditation schemes for testing laboratory which have direct impacts on the framework of the Regulations as well as the workload and ways this Department is going to administer the Regulations. In this respect, it is essential to review the framework of the Regulations before proceeding to the next stage of consultation.

EMSD started the in-house review in 1992 and in parallel, a consultant was commissioned to carry out a study on the proposed EPSR with an objective to establish an optimum approach in drafting the proposed EPSR. The review of the framework of the proposed Regulations has just been completed. This paper summarizes the approach to be used in the EPSR and discusses some of the final recommendations concluded.

## 5. THE CONCEPT OF ESSENTIAL SAFETY REQUIREMENTS

There are 5 safety requirements modelled from relevant internationally recognized technical specifications in the original consultation paper. These essential safety requirements (ESRs) will apply to the design and construction of electrical appliances at low voltage, which are intended to ensure, under normal use, the user's safety from -

a) electrical shock due to direct contact;

b) risk of fire or explosion due to over-heating;

c) personal injury due to loosened parts or overheated surfaces which are to be touched in using the electrical appliances;

d) danger due to improper use on account of lack of proper information; and

e) danger due to hazardous materials used in electrical appliances.

The consultant, however, proposed the use of broad essential safety requirements stated in the Low Voltage Directives (LVD) as adopted in European Community as the baseline for any national law development (please refer to reference 1 for details of LVD). The ESRs stated in LVD is considered to have the following relevant points :-

a) The ESRs stated in the LVD offers a wider and better scope for the protection of consumers;

b) The use of such ESRs is now a growing trend in the world;

c) The adoption of these ESRs will neither decrease the product manufacturers/sellers' obligations nor impose additional technical requirements to such manufacturers/sellers.

These ESRs will provide protection against hazards arising from the electrical product as well as protection against hazards which may be caused by external influences on the electrical product.

Hence, it is proposed to combine the original five ESRs with the ESRs adopted in the LVD the essential safety requirements for electrical products in Hong Kong.

## 6. CLASSIFICATION OF PRESCRIBED AND NON-PRESCRIBED PRODUCTS

The original concept of classifying electrical products into either prescribed or non-prescribed products is the worldwide trend and supported by the consultant. Prescribed products are those that are more liable to cause hazards and for which specific safety requirements are required in the Regulations. The Government is examining the list of prescribed products which would be stated in the EPSRs.

A tentative list of the prescribed electrical products is:

a) plugs and sockets;

b) adaptors;

c) lamp holders and starter holders;

d) unvented storage type electrical water heater.

Other products, not prescribed in the EPSR, are known as non-prescribed products. A reference list of non-prescribed products will be given in the Guidance Notes. (Please see Section 10 for introduction of Guidance Note.)

## 7. SAFETY STANDARDS

Choosing a suitable standard is always a difficult aspect of legislating for consumer protection in a situation where most of the consumer products in Hong Kong are imported from a variety of countries. The Government is considering the consultant's recommendations that a 'deemed to satisfy' approach be adopted in the Regulations and that compliance with the IEC standards or other national safety standards be recognised as one way of satisfying the ESRs. The responsibility for compliance will lie with the importers and local manufacturers. The compliance with the standards shall be considered as the preferred and acceptable means but not the exclusive route to achieve compliance. These measures offer higher flexibility to the enforcement authority, do not impose any trade barriers to existing trade partners and do not violate the degree of safety provision. A list of standards deemed to satisfy the ESRs will be given in the Guidance Notes.

## 8. MEANS OF COMPLIANCE

### 8.1 Prescribed Products

The Regulations will require that an electrical product under safety regulatory control shall be covered by a certificate of compliance. The certificate of compliance shall be issued by a recognized certification body with product tests reports submitted by accredited laboratory and quality assurance report to the manufacturer.

As an alternative option, a declaration of conformity issued by a RECOGNIZED manufacturer shall be accepted as a certificate of compliance. The subject of recognized manufacturer will be dealt with in Section 9(b).

### 8.2 Non-Prescribed Products

Basically the two alternative options mentioned above for prescribed products will be followed. Since non-prescribed products are less liable to cause hazards, it is proposed to accept the non-recognized manufacturer's declaration of conformity under his sole responsibility, without being under the procedures of a third party certification system, as an alternative means of compliance for the non-prescribed products.

8.3 The Regulations also provide an alternative route for innovative products without any international standards applicable.

## 9. RESPONSIBILITIES AND DUTIES OF VARIOUS PARTIES IDENTIFIED IN ENSURING SAFETY OF ELECTRICAL PRODUCTS

In drafting the Regulations, the responsibilities of various parties ranging from the manufacturer to the seller of electrical products have been identified as follows :-

### a) Manufacturer/ Importer

Either the importer or local manufacturer is responsible for the safety of the electrical products introduced to the local market. A manufacturer/importer will be liable for the design and construction of his electrical products to ensure compliance with the safety requirements stipulated in the Regulations.

## b) Recognized Manufacturer

Recognized manufacturer can issue declaration of conformity as certificate of compliance for his products.

The recognition of manufacturers will be based on the following documentary proof :-

(i) the manufacturer is registered with a quality system assessment body to ISO 9002; and

(ii) the manufacturer has a testing laboratory to EN 45001 or ISO/IEC Guide 25 for the purpose of product testing.

These recognized manufacturers have to be registered with EMSD. Moveover, for the purpose of acceptance as a certificate of compliance, the manufacturer's declaration shall conform to ISO/IEC Guide 22.

## c) Recognized Certification Body

Certification bodies require the services of separate testing, inspection and quality assessment bodies in their operation. Since Hong Kong has no national certification body in electrical products, the review explored the international market situation as most of the electrical products in Hong Kong are imported.

Test certificates from 27 member countries' national certification bodies under the Scheme of the IECEE, a merged organization of the International Electrotechnical Commission (IEC) and the International Commission for Conformity Certification of Electrical Equipment (CEE) for recognition of results of testing to standards for safety of electrical equipment (known as IECEE CB Scheme) will be considered as certificates of compliance, especially for imported electrical products. Further, electrical product manufacturers outside the member countries of the CB scheme including Hong Kong manufacturers, can apply for a CB certificate as one means of having a certificate of compliance. Since a large numbers of electrical products are imported from the U.S.A., which is not a member of the CB Scheme, certification from Underwriter Laboratories (UL) and ETL which are reputable certification bodies in USA are also under consideration. These provisions will provide adequate choices for overseas manufacturers to obtain a certificate of compliance. These recognitions will be stated in a schedule to the Regulations.

We have yet to establish certification bodies for local manufacturers in Hong Kong. Based on the criteria for a recognized certification body as stated in the consultant's recommendations which are basically contained in ISO/IEC Guide 28 and 40, we shall approach the three local HOKLA accreditated testing laboratories in the electrical product testing in this aspects.

## d) The Director

The Director shall administer these Regulations and keep a register of recognized certification bodies and recognized manufacturers.

## e) The Consumer

It is the consumer's responsibility, for his own personal safety to refrain from using an electrical product which has been prohibited by the Director. However, user will not be prosecuted if the electrical product does not comply with the requirements unless he knowingly uses or allows it to be used (i.e. after a notice has been served on him).

If an electrical product is found not to comply with the safety requirements, the Director shall prohibit its sale or use under the provisions of the Regulations. The Director shall also under these Regulations order the seller to withdraw all the products of the same description from sale or hiring out and to provide relevant information and details leading to the identification and location of the manufacturer or the origin of the product in question. The Director will also publicize the prohibited electrical products and warn the general public of the danger they pose.

# 10. GUIDANCE NOTE

An explanatory guidance note will be published shortly after the enactment of the EPSR to give guidelines on how the statutory requirements of the proposed regulations can be met. The major features of the guidance note shall include :-

a) reference list of non-prescribed products;

b) list of recognized standards;

c) other explanatory statement as deemed necessary for the proposed regulations.

It should be emphasized that the guidance note itself is NOT a statutory document.

## 11. IMPLEMENTATION

The industry will be consulted on the above proposals in early 93 and the draft Finalized Regulations shall be submitted to ExCo for approval by late 1993. The Regulations will come into operation 12 months after their enactment. This allows a grace period so that manufacturers, importers, purchaser-sellers can get acquainted with and conform to the safety requirements. A publicity campaign will also be launched with a view to achieving the widest publicity possible.

After the grace period, should there be any additional electrical products to be included as prescribed electrical products under the Regulations, the grace period will be shortened to 6 months from the date of promulgation of the additional prescribed electorial products.

## 12. CONCLUSION

The approach to formulate the framework of the proposed Electrical Product (Safety) Regulations was presented. It is hoped that members of the Hong Kong Institution of Engineers may give comments to proposed Regulations in the consultation stage and support the spirit of the Regulations to foster the safe use of electricity in Hong Kong.

## REFERENCE 1

### *LOW VOLTAGE DIRECTIVE (LVD)*

*PRINCIPAL ELEMENTS OF THE SAFETY OBJECTIVES FOR ELECTRICAL EQUIPMENT DESIGNED FOR USE WITHIN CERTAIN VOLTAGE LIMITS*

*1.* *General Conditions*

*(a)* *The essential characteristics, the recognition and observance of which will ensure that electrical equipment will be used safely and in applications for which it was made, shall be marked on the equipment, or, if this is not possible, on an accompanying notice.*

*(b)* *The manufacturer's or brand name or trade mark should be clearly printed on the electrical equipment or, where that is not possible, on the packaging.*

*(c)* *The electrical equipment, together with its component parts should be made in such a way as to ensure that it can be safely and properly assembled and connected.*

*(d)* *The electrical equipment should be so designed and manufactured as to ensure that protection against the hazards set out in points 2 and 3 of this Schedule is assured provided that the equipment is used in applications for which it was made and is adequately maintained.*

*2.* *Protection against hazards arising from the electrical equipment*

*Measures of a technical nature should be prescribed in accordance with point 1, in order to ensure:*

*(a)* *that persons and domestic animals are adequately protected against danger of physical injury or other harm which might be caused by electrical contact direct or indirect;*

*(b)* *that temperatures, arcs or radiation which would cause a danger, are not produced;*

*(c)* *that persons, domestic animals and property are adequately protected against non-electrical dangers caused by the electrical equipment which are revealed by experience;*

*(d)* *that the insulation must be suitable for foreseeable conditions.*

*3.* *Protection against hazards which may be caused by external influences on the electrical equipment.*

*Technical measures are to be laid down in accordance with point 1, in order to ensure:*

*(a)* *that the electrical equipment meets the expected mechanical requirements in such a way that persons, domestic animals and property are not endangered;*

*(b)* *that the electrical equipment shall be resistant to non-mechanical influences in expected environmental conditions, in such a way that persons, domestic animals and property are not endangered;*

*(c)* *that in foreseeable conditions of overload the electrical equipment shall not endanger persons, domestic animals and property.*

Paper No. 2

# IEE WIRING REGULATIONS - EVOLUTION FROM 14TH TO 16TH EDITION IMPACT ON THE CONTRACTORS

**Speaker : Mr. William Chan**
**Committee Member**
**Hong Kong Electrical Contractors' Association**

# IEE WIRING REGULATIONS
# EVOLUTION FROM 14TH TO 16TH EDITION
# IMPACT ON THE CONTRACTORS

Mr. William Chan

Committee Member
Hong Kong Electrical Contractors' Association

Paper No.

## SYNOPSIS

The IEE wiring regulation had been referred as bible for the trade in United Kingdom for the past decades since United Kingdom declared to be an EEC member.

IEE wiring regulation 15th edition taking into account the CENELEC requirement, was born with significant changes. This change exerted great impact to contractors, especially sub-contractor workers, to swallow and digest, thus resulting in loss of efficiency.

After a few years of practice, the 16th edition turned out to be highely acceptable by contractors as it provided greater freedom for them to justify their installation when alternative method was adopted.

In the 16th edition, the changes were very minor. The identification was formed by three part number for better clarity and the coverage of installation was further extended.

As a member in the industry, I believe the evolution of 14th to 16th Edition IEE wiring regulation will bring us to the harmonisation of International Standardisation.

## 1. INTRODUCTION

In the The pace of development in the IEE Wiring Regulations in the recent decades has been in a state of continual, progressive and rapid evolution. The launching of the 15th edition of IEE Wiring Regulations has resulted in an entirely new packing with a plethora of technical literature purporting to serve as guides and explanations since it was published in 1981.

The 15th edition, named 'Regulations for Electrical Installations' is considerably different from the previous 14th edition which was entitled 'Regulations for the Electrical Equipment of Buildings' and published in 1966. The 14th edition applied mainly to installations in and around buildings, whereas the 15th edition implied a wider scope of application such as agricultural and horticultural premises and constructional sites. In the 16th edition which was published in 1991, it has further extended the application to some special installations such as swimming pool and hot air sauna.

## 2. CHANGES FROM 14TH TO 15TH EDITION

The breakthrough of the 15th edition was that it was the first to take into account electrical installation rules agreed by the regional European Committee for Electrotechnical Standardization (CENELEC) as preparation for harmonisation with world-wide International Electrotechnical Committee (IEC) purporting to increase compatibility to trade among the countries of the European Economic Community or internationally. It was considered necessary to go back to basic fundamentals and concepts resulting in inevitably significant changes in the terminology, format, approach, plan and style adopted for the international standards and installation practices.

The impact of the 15th edition on the contractors had been very great because of the evolutionary changes mentioned above, in particular when put those regulations into practice in the construction industry in a very early stage.

The immediate effect caused to the contractors was that they had to give up using most of their long familiar terms, names and definitions as prescribed in the preceeding editions over the years. Many new terms coupled with new definitions were extensively introduced in the 15th edition. It was therefore not so easy for the installation contractors, especially for those sub-contractors' workers, to pick up within a period of time plenty of new terms such as circuit protective conductors (C.P.C.), exposed conductive part, extraneous conductive part, equipotential bonding conductor, residual current circuit breaker (r.c.c.b.), etc. Initially, many users of the 15th edition had experienced some difficulty in distinguishing between the various types of conductors arising from those generic terms.

## 3. EFFECT OF CHANGES FROM 14TH TO 15TH EDITION

3.1 The new format had resulted in different numbering system for regulations. In the 14th edition, the contractors could readily and simply refer to the relevant regulations by following the part (I or II), section (A to K) and then the regulation number (e.g. B.23). Whereas, the 15th edition used different enumeration which was obtained by the chapter number and then the section number, after which there was a dash and finally the regulation number. For example, 312-3, it was made up of Part 3 (Assessment of General Characteristics), Chapter 31 (Purpose, Supplies and Structure), Section 312 (Types of earthing arrangement), Regulation 312-3 (The type of earthing arrangement or arrangements to be used for the installation shall be determined). This new enumeration had brought anxiety to the contractors for a period of time to get familiar with the regulation numbers.

3.2 The 15th edition also adopted an entirely different approach, style and plan that could provide the design engineers and the contractors with a greater degree of freedom and flexibility than before. One particular advantage of the plan was that it was followed with logical sequence but not necessarily followed the sequence of the design steps used by the design engineers. In the case where the contractors involved some design work, they could follow the sequence of the plan quite logically and sensibly. For example, Part 3 Assessment of General Characteristics, Part 4 Protection for Safety, Part 5 Selection and Erection of Equipment, Part 6 Inspection and Testing. As one becomes more familiar with it and begins to appreciate that it is really a logical and objective approach.

As already mentioned, the 15th edition provided a greater degree of flexibility in its basic approach and style which was a considerable departure from the previous edition. This was because the 14th edition had been criticized by many users over the years that the guides and references provided were too limited and sometimes over stringent. For instance, the 14th edition adopted a table for the determination of the maximum capacities of steel conduits for the simultaneous drawing-in of single core PVC cables whereby one could recognise that one 20mm diameter conduit run could allow 10 numbers of 1.5mm$^2$ single core PVC cables under a condition that related to the conduit runs incorporating not more than two 90° bends. Whereas, the 15th edition provided a method which could be used to determine the size of conduit under various conditions necessary to accommodate cables of the same size, or different sizes and also provided a means of compliance with the relevant regulations. The method basically employed a 'unit system' such that each cable size being allocated a factor. Based on the same condition aforesaid, in the 15th edition the numbers of 1.5mm$^2$ single core PVC cables allowable in a 20mm diameter steel conduit were 12 which was obtained by dividing 270 (the data given in table 12D, Conduit factors for runs incorporating bends) by 22 (the other data given is Table 12C, Cable factors for long straight run or runs incorporation bends). In this respect, if the installation contractors desired to gain the maximum advantage from the 15th edition, it was advisable for them to design and plan how they could obtain an optimum result in an installation practice.

The 15th edition also provided a greater degree of freedom for the contractors to justify the methods adopted as alternative could always be available and the appropriate use of those regulations. For example, calculation of protective conductor size : The size of a protective conductor might be selected from Table 54F in Regulation [543-3]. Or alternatively it could be obtained by calculating the cross sectional area using the formula given in Regulation [543-2]. However, the basic requirement for achieving that was to have understanding on the essence and purpose of the regulations and its applications on the basis of practical experience so that those regulations could be properly and correctly interpreted and applied.

3.3 At the earlier stage of implementing the regulation requirements of the 15th edition, as reflected by many installation contractors was that they had suffered a lengthy period of uncertainty, confusion, discrepancy and perplexity that had resulted in considerably adverse impact on the contractors and workers. For example, as to the equipotential and supplementary bonding conductors, they were uncertain and very confused that how to bond the pipeworks, towel rail, window frame etc. in an effective and feasible way; where to locate most suitably the outlet boxes for the bonding conductors and what should be the correct size of bonding conductors e.g. the bond should have minimum cross section area of 2.5mm² if mechanical protection was provided or 4mm² if no protection was provided. During that period, they had encountered very often the problems that might require them to suspend / interrupt their progressing installation work schedule for a long period of clarification by the design engineers, to work repeatedly the installation works i.e. a lot of abortive works involved by trail and error to suit different individuals' interpretation and judgement on the relevant regulations, to provide extra materials and manpower for some complicated installation method (they regarded it might be departed from the traditional way of doing the work) suggested or required by the engineers and sometimes to provide plenty of times for the co-ordination among various trades for some sort of installation methods which could satisfy both regulation and engineering requirements. All these problems had incurred time and money losses to the contractors.

## 4. CHANGES FROM 15TH TO 16TH EDITION

The difference between the 15th edition and 16th edition has been comparatively not so great. It has therefore resulted in a lesser impact upon the contractors. The latest edition has taken further progress of the international development into account. The obvious change is that the regulations are identified by a three part number e.g. 312-02-01 for better clarity.

## 5. EFFECT OF CHANGES FROM 15TH TO 16TH EDITION

To some of the contractors, they may feel upset as they have begun to get used to the regulation numbers in the 15th edition and now they are required to refer to a further revised numbering system for those regulations, in particular when communicating with the others in the installation practice. However, it is believed that the contractors may be able to familiarise with it gradually, and begin to appreciate the clarity of it.

In the 16th edition, it has also revised and extended its scope of definitions such as danger, electrical equipment, fuse etc. to a wider range. Some familiar terms coupled with new definitions are added such as cable bracket, cable channel, cable cleat, cable ladder, cable tray, cable trunking and cable terminal, flexible wiring system. It has also added some entirely new definitions such as highway distribution board, highway distribution circuit, highway power supply, hot air sauna, etc.

In addition to the above, in terms of the format some of the explanatory figures and reference tables have been re-arranged / modified so as to obtain better clarity and simplicity. Cross references for the British Standards coupled with the relevant regulation numbers have been reinforced so as to obtain easier reference. The numbers of appendices have been reduced in order to make the regulations look more concise.

Further, some changes are found in the regulations which have been revised to suit the progressive development of the international standards. For example, the regulation number 537-02-04 under the section 'Isolation and Switching Devices' is a revised / added requirement in the 16th edition for a neutral link under a 4-wire three-phase supply i.e. the link shall comply with either or both of the following requirements :-

(i) it cannot be removed with the use of tools;

(ii) it is accessible to skilled person only.

In conclusion, no matter how the wiring regulations have evolved, the basic principles applied do not alter its initial attempt as established in the 1st edition in 1882 which was entitled 'Rules of Regulations for the Prevention of Fire Risks arising from Electric Lighting'. Over the decades, the regulations have been amended and modified from time to time to suit the advancement of electrotechnology. It is worth noting that the ultimate purpose of the wiring regulations is to serve as a guide for the provision of SAFETY from fire, electric shock and burns from electrical installations by applying good design, workmanship and proper materials. Therefore, the Regulations for Electrical Installations is not a wiring bible. The Regulations must be taken together with standard wiring manuals / code of practices stating sound modern practice in its most safe and economical way. The construction industry is progressively making headway. It is pleased to see that despite all the impact mentioned above on the contractors, the local contractors are able to cope with an internationally acceptable wiring standard and an improving installation practice.

Paper No. 3

# SAFETY CONSIDERATIONS FOR THE DESIGN, CONSTRUCTION AND OPERATION OF CABLE TUNNELS

**Speakers :** **Mr. C.T. Wan**
**Chief Electrical Engineer**
**and**
**Mr. K.T. Hong**
**Senior Electrical Engineer**
**The Hongkong Electric Co., Ltd**

# SAFETY CONSIDERATIONS FOR THE DESIGN, CONSTRUCTION AND OPERATION OF CABLE TUNNELS

Mr. C.T. Wan
Chief Electrical Engineer

Mr. K.T. Hong
Senior Electrical Engineer

The Hongkong Electric Co., Ltd.

## SYNOPSIS

Cable tunnels are special working zones with adverse conditions from the view point of safety of maintenance personnel and equipment. This paper describes the considerations and measures to ensure safety in the stages of design, construction and operation of two 275kV cable tunnels in The Hongkong Electric Co., Ltd.

## 1. INTRODUCTION

There are two 275kV transmission cable tunnels in the supply territories of The Hongkong Electric Co., Ltd. (HEC). The first 3.1 km long Wah Fu - Bowen Tunnel was commissioned in 1987. The construction of the second 5.7 km long Nam Fung - Parker Tunnel commenced in 1990 and scheduled to operate in March 1993.

Typical cross sections of these two cable tunnels are shown in figures 1 and 2.

Both cable tunnels are installed with double circuit 275kV single core oil-filled cables and accessories at present, with provisions for additional future circuits. There are also pilot and optical fibre cables together with auxiliary systems monitoring the tunnel environment and serving maintenance personnel.

The cable tunnel is a special working zone with adverse conditions against the safety of personnel and equipment. These factors include high humidity, high ambient temperature, possibility of toxic gas accumulation, fire hazard, confined environment with limited escape means, dependence on lighting and induced voltage from power cables.

In the design, construction and operation of the cable tunnels, the above factors should be considered and then measures incorporated to provide a safe environment for people working in the tunnel and proper operation of equipment apart from meeting statutory requirements.

The following sections describes the problems and counter-measures.

## 2. FACTORS AFFECTING SAFETY OF EQUIPMENT AND PERSONNEL

### High Humidity

The cable tunnels are under the central mountains of Hong Kong Island. Although the tunnel wall has watertightness treatment, it is unavoidable to have underground water leaking into the tunnel cavity. Under natural conditions, there will be little axial air movement in the tunnel to help evaporation and carry the moisture away from the tunnel. As a result, the high relative humidity in the tunnel is bound to be high. For the design purpose of equipment, 100% R.H. with water dripping is assumed.

### High Ambient Temperature

In the cable tunnel, there will be heat dissipated from power cables, lighting and electrical equipment. A portion of the heat will be dissipated to the earth mass via the tunnel wall, and the rest will cause temperature rise of the tunnel air. It is necessary to determine and control the tunnel air temperature below a prescribed limit for maintaining the maximum continuous current rating of cables and also provide a workable environment for maintenance personnel. A maximum tunnel air temperature of

40°C is therefore set for the design of equipment and comfort of people.

### Fire Risk

When a fire breaks out in the cable tunnel, it can be as disastrous as in a vehicular traffic tunnel. Due to the enclosed environment, the heat generated from burning objects will cause rapid rise in tunnel air temperature, and the smoke emitted will quickly filled up the cavity causing suffocation and impeding people identifying escape route. It is therefore essential to have equipment designed with minimum fire risk and does not propagate fire. Means should be provided to assist personnels to stay in the hostile conditions as long as possible.

### Limited Escape Means

The cable tunnel is totally enclosed with exits at both portals only. It takes about 40 minutes to walk from the middle of tunnel to the portal in case of the 5.7 km long Parker Tunnel. An efficient transportation facility is essential for normal inspection and emergency escape.

In case of emergency, people in tunnel may be frightened and act irrationally if not properly informed of the incident. They should be able to communicate with the outside world to report or be informed the nature, status and exact location of danger.

Means should also be provided so that people can easily identify their exact location and determining the right direction to escape.

These measures also serve to assist rescue team entering the tunnel to combat the problem.

### Toxic Gas Accumulation

During the construction and eventual operation of the tunnels, it is necessary to prepare for the worst possibility of toxic gas accumulation, including methane gas from soil, exhaust from people and machines. Forbidding diesel engines and control the use of gas torch welding in tunnel will minimize the chance of toxic gas evolution. Continuous measurement of the toxic gas content in the tunnel is required to alert operators for evacuation and initiation of forced ventilation in case of excess gas accumulation.

### No Natural Light Source

Inside the tunnel, the only light source comes from electric lighting. Power interruption will result in complete darkness since no natural light source is available. It is very dangerous to personnel working with rotary machine or electrical equipment if blackout happens suddenly, not to mention any psychological impact. A reliable power supply with redundancy for the tunnel lighting system is therefore of great importance.

### Induced Voltage From Power Cables

The 275kV cables installed in the tunnel are single core cables with a maximum fault level of 40kA. Pilot cables laid alongside the power cable will experience transient induced voltage during fault condition, the value depending on the length in parallel with and separation from the power cables. When the route length is long and the maximum longitudinal induced voltage in auxiliary cables might reach 15kV.

The voltage rise of the earthing system of end substations in which the pilot cable terminated has also to be added vectorially to the induced voltage.

In Parker Tunnel which is 5.7 km in length, the maximum voltage induced in each pilot cable conductor, during a single phase to earth fault current of 40kA in a 275kV cable laid in the same trench, may reach 970 volts per km of parallelism or about 6 kV in total between substations.

The cable insulation and terminal equipment must withstand such high transient voltages and provided with means to protect personnel working on it.

## 3. SAFETY MEASURES IN DESIGN OF TUNNEL AND EQUIPMENT

### Tunnel Shape And Size

Prior to civil work design, detail site investigation were carried out in order to estimate the type of ground to be encountered during excavation and to provide the necessary information.

To achieve best structural support and minimize the chance of collapse, the tunnel roof was decided to be circular. The size and ground slab of tunnel were determined to allow for the passage of maintenance vehicle.

The Bowen Tunnel passed through the volcanic rocks beneath Mt. Kellett and Mt. Gough, the construction was by conventional drill and blast method. The tunnel section is of horseshoe shape.

The Parker Tunnel, which is of perfect circular section, is excavated by a Tunnel Boring Machine (TBM) through the hard granite rock layers of Mt. Nicholson, Jardine's Lookout, Mt. Butler and Mt. Parker.

### Watertightness

To minimize water dripping, the watertightness of the completed tunnels are specified such that the groundwater leakage rates do not exceed 1.0 litre/hr for single leaks and 0.2 litres/m}/hr for any 10 metre length of tunnel. The permanent tunnel wall lining must be constructed to meet the target by selecting shotcrete with the correct properties, proper method of placement of concrete, spray of shotcrete, treatment of construction joint and arrangement for cavity grouting.

### Drainage

To prevent water accumulation, the longitudinal profile of the tunnels are of inverted V shape with 6% fall in both directions.

The water leaked into tunnel is allowed to drain into a granular material subdrainage layer and collected by a 200mm diameter porous pipe leading out to the portals for discharge to urban drainage system.

### Installations And Enclosures

Due to the high humidity and water dripping, all enclosures, cable marshalling boxes and auxiliary equipments supplied for installation inside the tunnel were specified to be not less than IP54 of the Ingress Protection code of BS5490. Lighting switches are specified to IP65.

All metallic material are specified to be made of stainless steel or hot-dip galvanized.

### 275kV Oil-Filled Cable

The main equipment in the tunnel is the 275kV single core oil-filled power cables with PVC oversheath. It will be easy to install these cables inside cable trench or hanging on cable tray and cooled in air. However, in case of fire, there is risk of oil leaking out from cable and result in rapid propagation of the fire. The burning of PVC will also emit poisonous gases and large quantity of smoke. An alternative is to use solid dielectric insulation and fire retardant cable sheath which was found too bulky and also very costly. Taking into account the factors of better cooling and mechanical protection of the cable when surrounded with soil, direct burial method with sieved soil or controlled backfilling material was adopted.

The hydraulic system of the oil-filled cable is also designed to minimize the number of cable joints in the tunnel and that no cable oil feeding tank is installed inside the tunnel.

### Low Smoking Power Cable And Wiring

To avoid emission of smoke and corrosive gases when burning due to internal fault or external fire, all exposed low voltage cable and wiring should be carefully selected.

In Bowen Tunnel, low voltage power cables were laid on cable ladder without any enclosure. Low smoking armoured type cables with construction of XLPE/LSF/SWA/LSF complying with BS6724:1986 (3) were used.

In the Parker Tunnel, L.V. cables are to be buried underground in a service cable trench and hence normal steel wire armoured cables are used.

At branch off to distribution boards, the cable is enclosed in galvanized steel conduits.

For wirings from power distribution board to power sockets and lighting points, single core low smoking cables are used in galvanized steel conduits. They are of zero halogen and low acidic gas emission (less than 0.5% by weight when tested in accordance with IEC 754-1).

Internal wiring of lighting luminaires are of heat resistant, flame retarding PVC insulated cables.

### Fire Services Installation

After consulting the Fire Services Department (FSD), it was agreed that since the tunnel would be used exclusively by HEC and that all cables are buried, thus reducing immensely the possibility of fire, an automatic fixed installation is considered not required. To enable the fire brigade to go in the tunnel and communicate with the control station outside tunnel, the following provisions were considered:



Pap No.

(a) Access for emergency vehicles to reach the portals.

(b) Emergency lighting.

(c) Portable fire extinguishers at regular intervals.

(d) 15 Amp. power points for F.S. equipment at regular intervals.

(e) Exit and directional signs.

(f) An internal telephone system.

(g) A radio communication system which could be utilized by FSD in emergency.

In both portals, only the transformer rooms and cable oil tank rooms are protected by automatic Halon (BTM) or $CO_2$ system. The other plant rooms are provided with automatic fire alarm system using smoke and heat detectors.

Portable B.C.F. fire extinguishers are provided in each portal and at 100m intervals along the tunnel.

A 270 litre foam fire fighting trailer is also provided for fire fighting inside the tunnel.

Other requirements listed above are also fulfilled as described in following sections.

## Lighting And Power

To ensure security of supply to lighting and power points, power is normally fed from the two substations at each portal. Each substation feeds approx mately 50% of the load through independent systems incorporating 11kV Ring Main Unit (RMU), transformers, L.V. switchgear and final distribution cabling and MCB boards. The 11kV RMU can be remote switched from System Control Centre through computer remote terminal unit and pilot cable of the distribution network. Connected to the RMU are 2 nos. of 11kV XLPE cable fed from different sources.

There are also standby L.V. supply to the two substations from the distribution network.

There is no standby diesel generator installed in the substations since all emergency installations are battery operated.

For tunnel lighting, corrosion resistant luminaires are used. To avoid moisture condensation inside the luminaires due to high humidity, the normal lighting is controlled by daily-timer to switch-on for at least 1 hour per day.

## Emergency Lighting

In the event of a total power failure, it is necessary for a number of luminaries to remain alight. Self contained M/3 (BS5266(2)) emergency lighting luminaires are installed under the crown of the Tunnel at 16m intervals to provide minimum illuminance of 0.2 lux along centre line of the tunnel and escape route.

As the emergency luminaires are mounted at ceiling height where the surrounding air might reach 40xC, high temperature type sealed maintenance-free nickel cadmium battery is specified.

A nominal operating period of at least 3 hours is maintained at the time of normal supply failure.

## Mechanical Ventilation

The tunnel ventilation system serves to maintain the tunnel cavity temperature less than 40°C so as to attain the optimum current rating of the 275kV cables, and to supply enough fresh air for personnel safety and comfort.

To estimate the air flow quantities required to remove the heat dissipated from the power cables to the tunnel air and hence the ventilation system capacity, a heat transfer simulation study using finite difference analysis by computer were conducted in the design stage.

The two cable tunnels have basically a single push-pull longitudinal ventilation system. Air is drawn through the tunnel at one side of the portal and then extracted to the ambient at the other portal. Air flow is normally set in one direction but it can be reversed in emergency for smoke extraction.

The ventilation system is set to automatically operate by a timer for 2 to 3 hours continuously daily to drive out humid and stale air, or when the tunnel air temperature exceeds 38°C, or when the concentration of methane gas exceeding 500 ppm. Local manual operation is available at control panels located at both entrances to the tunnel for necessary air purging or emergency operation.

### Tunnel Monitoring Sensors

For the control and monitoring of tunnel conditions, temperature sensors, relative humidity sensors, methane gas detectors and pressure sensors are installed at regular intervals, usually at 275kV cable joint bays. These signals were transmitted to a computer remote terminal unit at the portals and then relayed to the System Control Centre. People working in tunnel would be informed of any abnormal conditions at an early stage.

### Communication

Private automatic exchange telephone system (PAX) is installed inside the cable tunnels for direct communication with personnel at portals and System Control Centre. Wall-mounted industrial type flameproof telephone sets are installed inside the tunnel at 200m intervals. Steel wire armoured 15-pair pilot cables are laid along the tunnel and terminated in IP54 marshalling boxes adjacent to the telephone sets. Standard telephone sockets are also provided at 20m intervals for using portable telephones.

In Bowen Tunnel, there are also push-button type panic alarm panel at 100m intervals which are wired up into 6 groups to initiate audible and visual alarms at local alarm display consoles located at either end of the tunnel. By this, personnel posting at the portals can quickly identify the location of emergency. The alarm will also be sent to System Control Centre via the RTU.

In Parker tunnel, a VHF radio communication system with two channels is installed covering the whole tunnel. This system is a two-way radio system using two leaky coaxial cables. Working personnel inside tunnel can make direct contact with people outside and System Control Centre with portable radio. With this effective radio system, no panic alarm system is required and the interval between telephone sets could be increased to 500m. The radio system also provides an additional means of communication for FSD in emergency. A control switch is incorporated in one of the coaxial cable so that FSD may plug in their own portable radio system at specific plug-in locations at either portal for their exclusive use of the coaxial cable.

### Remote Control System

In each portal substation, there is a RTU for remote supervision of the ventilation system, indication of alarms from fire services installation, methane gas detector, tunnel air and soil temperature, panic alarm system and intruder alarm system.

Alarms for tripping important circuits of the L.V. power supply system will also be sent to System Control Centre to mobilize maintenance staff without delay.

### Directional Signs

Self-luminous directional signs indicating the direction and distance from each portal are installed at 100m intervals and alongside the panic alarms for easy identification of escape direction.

### Inspection Vehicle

Battery driven vehicle is employed for inspection, transportation of worker and material inside the tunnel. The compartment is air-conditioned so that people can stay inside the vehicle even the tunnel cavity is filled with smoke.

The maximum towing capacity is 900 Kg while carrying 4 persons. It can tow the foam fire fighting trailer or cargo trailer. The maximum speed of the vehicle in tunnel is limited to 15 km/hr.

On the vehicle, there are gas detector with alarm connected to the detector control panel inside the vehicle. There are also breathing apparatus, first aid kit and a collapsible stretcher.

### Measures Against Induced Voltage

Pilot and telephone cables laid in the same trench of 275kV cables are made up in twisted pairs and with metallic screening to reduce the induced voltage between conductors. The insulation of the conductors is able to withstand a test voltage of 15 kV r.m.s. for one minute between conductors and between any conductor and earth.

Pilot cables entering substations are terminated at marshalling boxes equipped with 15kV insulated terminals, isolating link and earthing facilities for work on the pilot conductor. Each pair of pilot cable for protection purpose and oil gauge alarm is connected to the terminal equipment via neutralizing transformers.

Surge arrestors are fitted in telephone sockets and marshalling boxes for protection against transient voltages.

A low earthing resistance at terminal substations and marshalling boxes inside tunnel is also important to limit the earth potential rise during fault. In the Parker Tunnel which is surrounded by high soil resistivity hard granite rock, two number of 150 $mm^2$ copper earthing wires are laid throughout the whole tunnel interconnecting the two end substations to ensure a low resistive path for earth fault current. These earth wires also provides earthing points for connection to installation inside the tunnel.

## 4. SAFETY MEASURES DURING CONSTRUCTION

### Civil Aspects

When drill and blast method was adopted, blasting was not to be carried out when thunder storm signal was announced by the Royal Observatory to avoid explosion triggered by lightning.

After blasting or excavated by TBM, loss rock on surface were removed to ensure no falling rock to endanger work. Temporary tunnel wall lining by shotcrete or steel arch ribs was applied where applicable to prevent tunnel collapse.

Temporary ventilation was provided for people working in the tunnel. Measurements during construction stage of Bowen Tunnel showed that the available natural ventilation through the tunnel, with tunnel doors widely open were 9 $m^3/s$ in summer and 3 $m^3/s$ in winter. These values have been verified to render a safe working environment for respiration, removal of exhaust of respiration for 100 people and air for combustion of 3 gas torches. Hence it is still safe to work in the tunnel under normal circumstances even when ventilation system does not operate.

Temporary lighting and power was provided throughout excavated portions.

### Prevention Of Toxic Gas Accumulation

- Electric tools rated at A.C. 110V are used in the tunnel.
- No engine or tools consuming diesel fuel is allowed inside the tunnel to prevent exhaust gas generation.
- Motorized cable rollers and caterpillar machines are employed for power cable laying instead of the conventional pulling by engine winch method.
- Mixing type compound is used to fill up the fibre glass coffin of 275kV cable joint instead of bitumen compound which requires long time boiling by gas burner. Solder wiping of power cable joint is made by small gas burners and the number in concurrent use is controlled.
- No smoking is allowed in the tunnel.

## 5. SAFETY MEASURES IN OPERATION

For the safety of personnel, HEC has imposed a code of practice for all personnel intending to gain access to and work in the cable tunnel. The document is displayed at the entrances of tunnel.

The main points are:

- The mechanical ventilation system shall be operating for minimum 30 minutes to purge the air in tunnel before people go in.
- The entrance door shall be locked open so long as there are personnel inside the tunnel.
- The inspection or maintenance team shall consist of minimum 2 members who are competent to use gas detector and breathing apparatus.
- Confirm there is no methane gas alarm and/or tunnel temperature high alarm before going in.
- At each portal, a person is assigned as a Safety Watcher for communicating with those inside the tunnel and with System Control Centre. He shall make constant contact with the working personnel at 30 minutes interval.
- Inspection personnel shall wear safety helmet fitted with battery-operated headlamp or carry a hand held battery-operated torch.
- In the event of emergency or methane gas or high temperature alarms, people shall wear breathing apparatus immediately and retreat to the nearest portal.

## 6. CONCLUSION

In the design, construction and operational stages of the two 275kV cable tunnels in HEC, various adverse conditions of the cable tunnel were considered and appropriate measures incorporated to ensure the safety of personnel and proper operation of equipment.

From the construction and operational experience of Wah Fu - Bowen Cable Tunnel since 1987, there is no major accident reported on human injury. Some minor problems were reported on deterioration of delicate equipment due to high humidity and temperature or human mal-operation of panic alarm system.

In the second cable tunnel, electronic equipment installed in the tunnel is kept to the minimum and the panic alarm system is replaced by VHF radio system. It is expected that the failure rate of equipment will be much reduced and the good safety record maintained.

## ACKNOWLEDGEMENT

The authors are grateful to The Hongkong Electric Co., Ltd. for permission to publish this paper.

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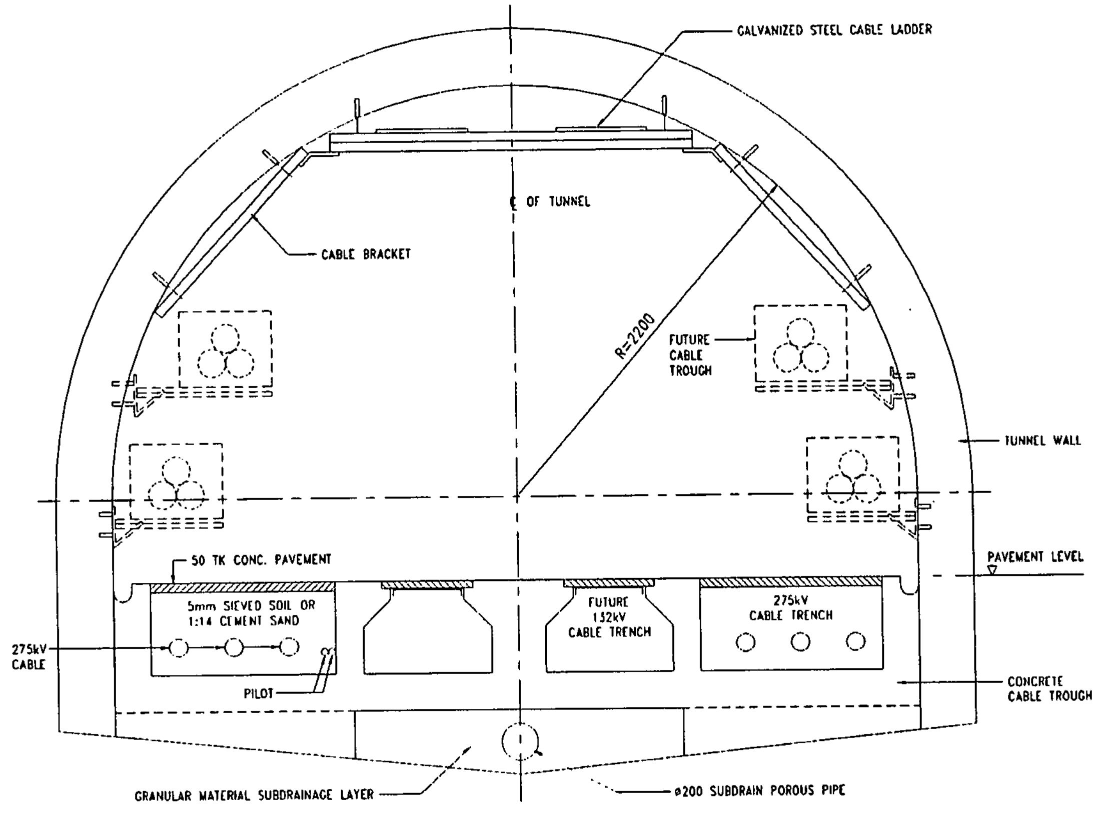


FIGURE 1 : TYPICAL SECTION OF WAH FU - BOWEN CABLE TUNNEL

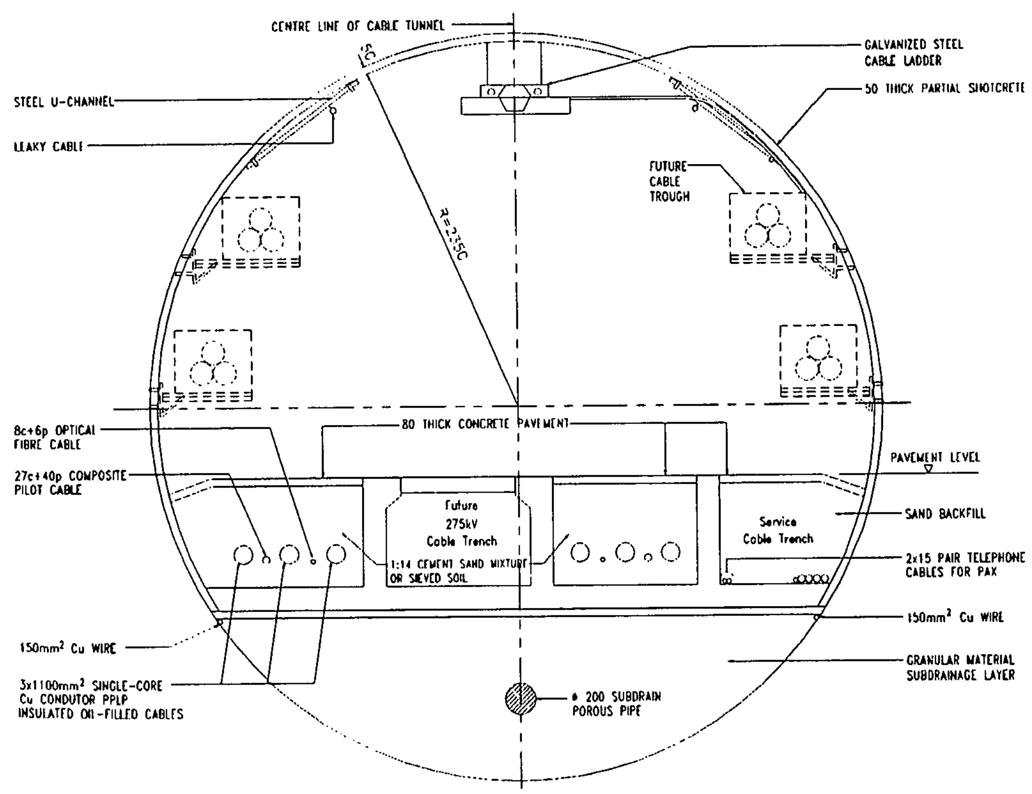


FIGURE 2 : TYPICAL SECTION OF NAM FUNG - PARKER CABLE TUNNEL

Paper No. 4

# MEASURING SAFETY PRO-ACTIVELY

**Speaker : Mr. Russell Powell**
**Five Star Safety & Health Management Programme Consultant**
**China Light & Power Company Ltd**

# MEASURING SAFETY PRO-ACTIVELY (CLOSING THE DOOR BEFORE THE HORSE BOLTS)

Mr. Russell Powell

Five Star Safety & Health Management Programme Consultant
China Light & Power Company Ltd

## SYNOPSIS

The purpose of this paper is to briefly discuss the concept of measurement for safety and to provide insight into the benefits of measuring safety performance pro-actively, prior to accidents occurring.

## 1. INTRODUCTION

No manager, engineer or supervisor will in this modern day and age, accept that it is inevitable that people are going to die, be maimed or injured as a result of economic activity.

Occupational and work safety is generally accepted as a common value by both employers and employees. However as Bertrand Russell once said "One of the troubles of our age is that habits of thought cannot change as quickly as techniques, with the result that as skill increases, wisdom fails".

One of the greatest tasks we have today is to keep safety in line with the rampant advances in technology.

Why measure safety? Tom Peters and Robert Watterman Jr. (1982) in their book In Search of Excellence put it most aptly when they said "What gets measured, gets done. Putting a measure on something is tantamount to getting it done, it focuses management attention on that area. Information is simply made available and people respond to it!" What is evident in this analysis, is that measurement is a means to an end and not an end in itself.

Measurement is primarily a management tool which is used as a yardstick against which the achievement of objectives or conformance to standards can be clearly quantified. Almost anyone can quite easily measure the outputs of an organization in tons, sales, dollars etc. Yet in order to get on top of those inputs which affect the results, management needs to measure the actual situations which are creating the results. This would enable management to make pertinent and quality decisions within the context, indicated by the objective criteria which have been measured and expressed in numbers.

Until recently virtually all measurement relating to safety has sadly required an accident or injury to have occurred.

We have merely tended to tally up the total number of accidents, record the types of accidents and classify them. This would in turn produce comprehensive sets of statistics telling us what not to do in future.

The severity of an accident was usually the indication as to the level of attention paid to that particular incident. A fatal accident would be investigated in depth and a minor injury would receive less attention.

What is in fact being measured by measuring accidents, is failure. Bird and Germain (1986) referring to measures of accident frequency and severity rates refer to these measures by stating that "they are measurements of 'unsafety', and tell you nothing about the nature of your problems or what to do about them". In essence the major drawback is that the usefulness of such statistics is limited, as they can only indicate problem areas which have previously, under similar conditions, lead to accidents.

This data cannot predict future accidents and therefore does not provide an indication of the success of pro-active precautions, suggesting that this type of measure is management reaction rather than management control.

The basic problem with moving away from the measurement of loss-type accidents, is that inevitably one moves into less tangible concepts, yet the key to management control is measuring performance in quantifiable, objective terms would entail the defining of what "safety" is and how to measure it.

Safety has been defined ad infinitum by the various writers in safety management yet the simplest most meaningful description in my view, is to regard safety as:

"a morally acceptable degree of risk".

This implies the assumption that safety is a relative concept, not an absolute, with safety never being 100% safe.

This allows us to look more definitively on measuring safety performance. The simplest way is to determine to what degree minimum safety standards are being met, specifically the measurement of control which is in place to prevent accidents.

The obvious question which arises is "which standards should safety be measured to?"

A number of systems of safety measurement have been developed over the years which all attempt to establish a comprehensive set of general requirements and minimum standards which relate to the scope of safety management. (The various drawbacks and merits of the proprietary systems will be excluded from this discussion)

These general requirements and minimum standards have been found to hold true for the vast majority of productive and work processes, through the course of evaluation over the years.

The significance of these sets of standards is that they create a objective framework against which we can measure the actual physical conditions within which work is performed as well as the level of systematic control management has over the work process. This would result in a measurement which reflects accomplishment as a percentage of standards.

The evaluation of safety performance becomes the determination of the degree to which a standard or standards have been met. This provides the essence of safety in the work process by pinpointing which standards are being met and which not, what is working well and what requires management attention. By identifying substandard performance before an incident has occurred, pro-active corrective action can reduce the probability of accidents in the identified area. The measure of the relative degree of compliance provides management with information which goes beyond the subjective statement. A statement of 82% compliance with standards conveys a far greater message to a management team than some safety officer reporting a "quite good" status of safety.

The net result is that the quality of decisions improves and the allocation of resources available can be maximized. Priorities become self evident as the risk profile of the organization is reflected in these measurement scores.

One of the benefits that such a system has, is that is can be self monitoring as well as externally audited. The self monitoring process allows management to objectively identify good safety performance, enabling appropriate and justified commendations. In addition it allows the prompt identification of areas which can be corrected, thereby preventing potential loss incidents.

An external audit of a company's safety system by a trained specialist safety auditor would provide information which may not immediately be apparent, yet may be fundamental to the safe operation of the business. Systematic professional safety audit techniques subject the management systems to rigorous scrutiny. This is to identify whether the systems in place are in effect creating the physical work environment that they were designed to achieve. This external view is also independent of any management and organizational processes in the company and hence reflects a clearer picture as to the risk profile of the business unit.

To bring the concept closer to the concrete reality of Hong Kong, please allow me to use the example of China Light and Power Company, who have implemented the "5-star Health and Safety Management System(TM)[1]".

The implementation entailed the comprehensive independent safety audit of twenty four (24) identified strategic units within the company.

The benefits derived were not limited to the greatly improved physical conditions of work, but also became a key factor in both management and worker motivation. For the first time in Hong Kong history, a company worked an accident free period of 1.6 million manhours[2] during December 1991 and January 1992.

Furthermore the impact on efficiency and productivity were evident, with a corresponding lower level of inventory.

The number of accidents as well as absenteeism through sick leave decreased notably, indicating a general improvement of the work environment.

## 2. CONCLUSION

It is apparent that focussing on the quantification of conformance to a general set of safety standards enables a company to reach the fundamental purpose of controlling the work environment. This objective measurement of the inputs required for good safety performance allows for appropriate action to be taken within the parameters of the normal operating cycle of the organization.

In so doing, the factors directly related to the proper and safe operation of the business enterprise are addressed on a continuing basis.

This can be achieved before any accident or incident could occur, reducing the financial burden and human costs of learning.

*1. *The 5-Star Health and Safety Management System is a proprietary safety system purchased and used by China Light and Power.*

*2. *Accident free as measured against the ANSI Z16 Standards.*

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# THE ROLE AND DEVELOPMENT OF PROTECTION IN THE SAFE OPERATION OF POWER SUPPLY SYSTEMS

Mr. N.F. Chin

Export Sales Manager
GEC ALSTHOM Protection & Control Ltd

## SYNOPSIS

The role of protection in the safe operation of power supply systems is examined. To fulfill this role to meet the increasing demand of modern power systems for better performance the latest developments in protection relays are presented. The advent of digital technology provides the tools to design relays with better performance, flexibility and facilities. This new generation of relays also enable a new concept of hardware construction, implementation of old ideas and new applications that were not possible in the past.

## 1. INTRODUCTION

Power supply systems are not static, but changing continuously to meet the energy demand of consumers by generating the electricity required and using the most effective transportation means. Ensuring their safe operation demands appropriate equipment to handle different situations. The purpose of this paper is to examine the role of protection and how the latest developments, using proven technologies to implement new ideas and to improve old ones, helps to enhance this role.

## 2. POWER SYSTEM PROTECTION AND ITS ROLE

The main objective of protection in the operation of power supply systems is to remove unwanted conditions - faults, disturbances or abnormal operating conditions, so as to maintain continuous operation of the healthy parts of the system. This removal process must be effected with maximum if not absolute selectivity, dependability and reliability, and at reasonable cost. The protection is to ensure that there is no danger to the maintenance of supplies to consumers or damage to equipment, whilst ensuring the safety of the operating personnel.

It should be noted that protection embraces three components i.e. the signal sensors/transducers, abnormal-condition detectors and switching devices to remove the undesirable conditions. The role of protection to ensure safe operation of power supply systems should therefore include contributions from all these components. This paper will concentrate only on the role of protection relays as abnormal-condition detectors. However it must be emphasized that the overall performance depends also on the correct operation of the sensors/transducers and the switching devices.

Protection relays play the most important role in the process of protecting power supply systems. Relays of different operating characteristics are required to respond to particular system conditions and to take appropriate actions.

Protection relays may be broadly classified on the basis of their functions:

- fault detectors such as short-circuit overcurrent relays and others that are applied to detect actual faults on the primary systems.
- undesirable-disturbance detectors to deal with situations not involving actual system faults but relating to system phenomena such as unstable system oscillations
- abnormal-operation detectors to ensure the operation of plants or circuits is within their safe design limits.

The role of protection relays is therefore not necessarily restricted to the detection of solid faults on power systems, though this function appears to have become synonymous with protection relays.

Relays of special operating characteristics are designed to deal with disturbances that may cause operational problems. An example is power-swing tripping relays used to detect unstable system

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oscillations and initiate de-coupling of the system into sub-systems at electrically strategic point(s) in order to save the complete system from collapsing.

To ensure safe operation of plant items such as transformers and motors, protection relays of different characteristics are used to detect any abnormal operating environment such as overloading without involving any electrical faults.These relays are generally not suitable to cover actual fault detection.

Despite the well defined and emphasized function and objective, to ensure safe operation of power systems, protection relays are not considered as safety-critical items. Safety-critical devices or systems are those processes, products and services where a breakdown or design fault might lead to a situation where human life is at risk. Other interpretations widen the scope to cover hazards such as major injuries, damage to property and environmental pollution.

Individual relays are not classified as safety critical despite their obvious safety role for two reasons:

- they are not intrinsically dangerous in themselves

- they almost always operate in an environment where they are supported by duplication or back-up systems with the level increased in proportion to the risk envisaged.

## 3. DEVELOPMENT IN PROTECTION RELAYS

To achieve the objective of contributing to the safe operation of power systems there is a continuous search for ideas and technologies to improve existing protection relays in terms of performance, flexibility and facilities.

The latest development centres around the application of proven digital technologies in the design of relays. This takes place in an evolutionary approach to deal with traditionally conservative thinking in the application and design of protection relays.

The use of computers in high voltage substations has been considered since the 1970's, at first for monitoring and control applications and later for protection functions. In the early 1980's commercially available microprocessor-based protection relays for distribution systems appeared. Protection relays which have been developed for high voltage applications over the past five years have, in the main, been microprocessor-based.

The advent of digital technologies and their successful application in power system protection have brought about considerable changes in the field of power system protection.

### Hardware

The use of digital technology enables a new concept in the development of relays in terms of hardware. The concept of standard hardware becomes a reality. Figure 1 shows the general structure of a digital relay with the software for the protection function determines the characteristic of the finished product. The protection function algorithm ensures the hardware is tailor-made to perform the designed function.

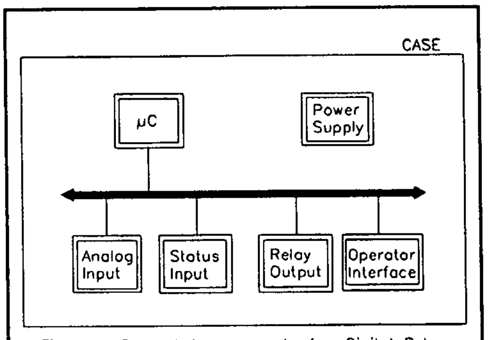


Figure 1 General Arrangement of a Digital Relay.

Figures 2 and 3 show two examples of standard hardwares used to design protection systems for transmission and distribution systems respectively.

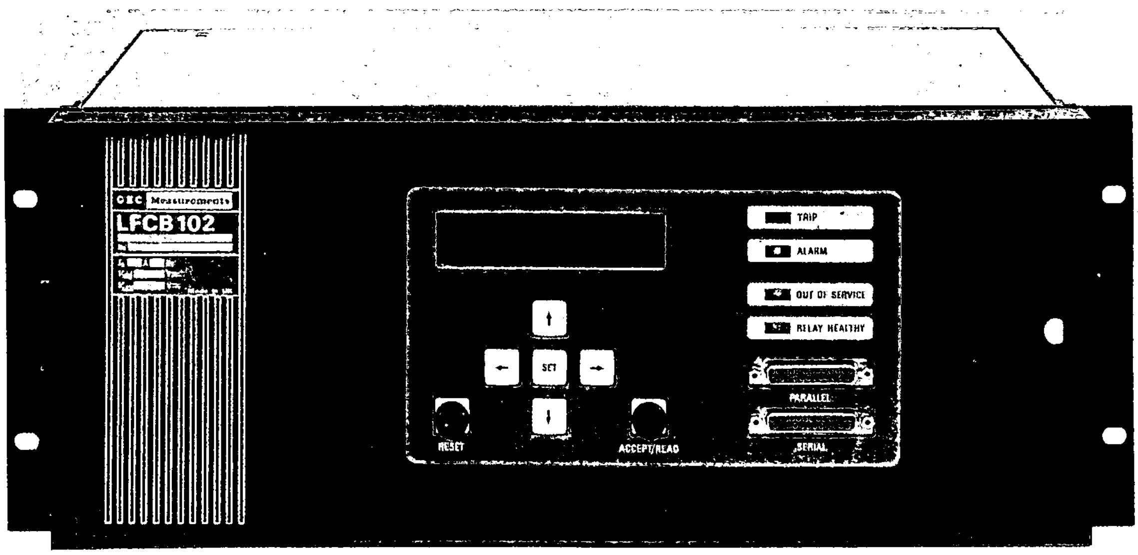


Figure 2 Standard Hardware for Transmission Line Protection

This use of standard hardware has a number of benefits both to the manufacturers and to the end-users. To the manufacturers it means less development time for design changes and prototype testing, and easier modification to suit special applications. To the users, expenditure on staff training and spares holding are less and it enables easier maintenance and testing of the equipment.In the design process it also provides a certain degree of standardisation in the software design by using standard operating systems and a library of utility programmes.

## Implementation Of Old Ideas

The use of software algorithms to develop protection functions has enabled the implementation of old ideas of protection that were not possible or too complicated using old technologies based on either electromechanical or solid-state analogue design.

A typical example is the application of Kirchhoff's law in designing differential protection applied to the protection of feeders. Numerical techniques enable a true differential comparison of all the currents entering and leaving the protected feeders on a phase-by-phase basis. This provides a cost-effective design of protection scheme for multi-ended feeders with much improved performance levels enabling wider use of this form of transmission line configuration and requiring less capital investment.

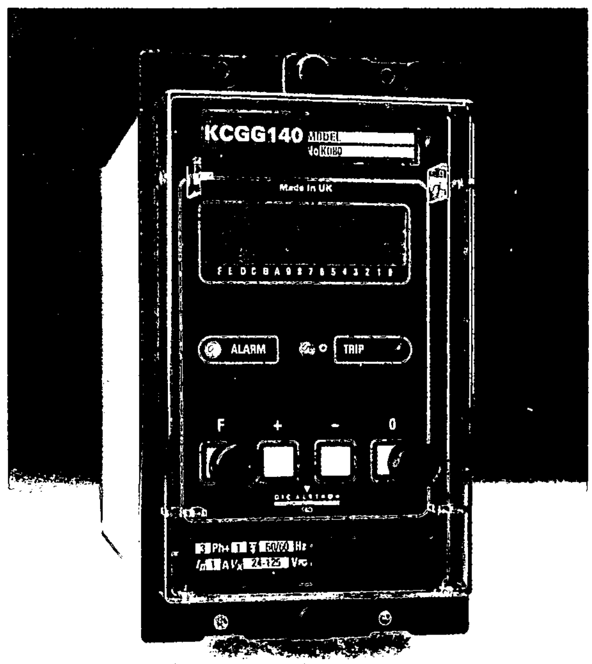


Figure 3 Standard Hardware for Distribution System Protection

Another example is the application of superposition theory. It is well established that during a fault the condition can be analyzed by separately considering the situation being consisted of a pre-fault component and a superimposed fault component. This is illustrated in Figure 4 showing the voltage and current signals consisting of the two components.

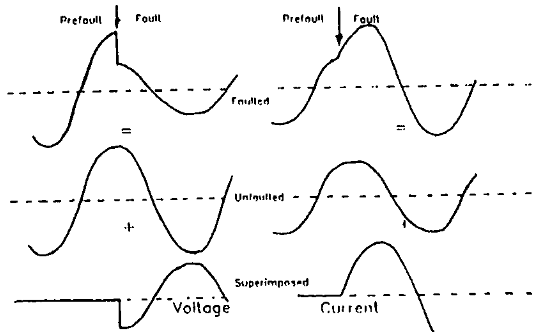

Figure 4 Extraction of Superimposed Component.

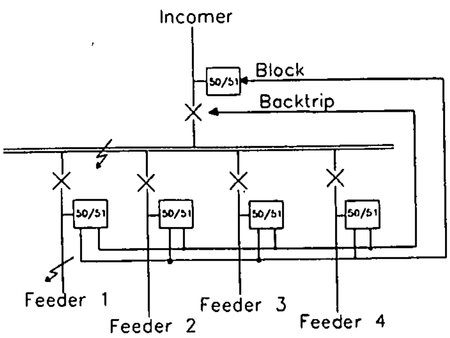

Figure 5 Non-Cascading Arrangement of Current-operated Relays.

The ability to extract the faulted component enables the design of directional elements that have a much better performance level compared with conventional directional element design. By comparing the superimposed fault voltage and current signals for the two conditions of forward and reverse faults it can be shown that there is a polarity change between the two conditions, thus providing a criterion to determine whether a fault is in the forward or reverse direction. In addition phase selection can easily be achieved to identify the faulted phase(s). With two directional relays on either end of a feeder, a scheme can be set up through the use of a simple communication link that can differentiate an internal fault, where the two end directional elements will operate, from an external fault where only one element will operate. Tripping of the two end circuit breakers is effected by the operation of the two end directional elements coordinated through the communication link.

The readily extracted superimposed fault component enables a wide range of protection functions being considered and implemented, such as phase comparison, fault location and phase selection.

## New Applications

The latest range of digital relays has also enabled new applications to improve the protection of the primary supply systems.

For distribution systems one such improvement is in the use of a non-cascading arrangement of current-operated relay operations within a localised distribution network. This is illustrated in Figure 5.

Through the use of a start function output from the downstream relays, say on outgoing feeders, the upstream relays, say on the incomer, can be blocked from operation for a pre-set time. This will enable the outgoing feeder relays to operate first. The pre-set time required is less than the normal grading margin and the whole system is set up in a non-cascading arrangement.

This use of `start output' and `block input' facilities also provides additional protection functions that were not justified on a cost basis for distribution systems. These include busbar protection and circuit breaker failure protection.

Consider Figure 5 again: If the outgoing feeder circuit breaker fails to operate the associated feeder relay will recognise this condition through its current level detector and pre-set time delay. The start output will be removed to enable operation of the incomer relay and tripping of the incomer. If a busbar fault occurs the incomer relay, not receiving any block signal from downstream relays, will trip very fast, say in 50 ms. For a network with multiple infeeds directional control is required to coordinate the start/block functions.

Another new application is the ability to desensitize the protection relays during cold start conditions in the primary systems such as the starting of motor loads. In the past the relay settings had to be adjusted to enable this healthy condition not to cause tripping of the circuit breaker with the consequence of reduced sensitivity for actual fault detection. The new generation of relays can either have an adjustable delay in the relay output to prevent mal-tripping until the end of starting period or be switched to an alternative setting group of higher settings stored in the relay to desensitize its operation during the starting period.

### Improvement Of Relay Performance

New technologies have enabled the design of relays with very much improved performance. For distribution system protection using current-operated relays the improvement includes selectable operating characteristics of the relays, adjustable resetting characteristics and selectable response control in terms of fault direction detection.

The availability of multi-characteristics within a single current-operated relay has made the application of overcurrent and earthfault protection much more flexible and refined and has provided a means of standardisation on hardwares. The most recent development in this area is the use of an operating characteristic that is self adaptive to the primary system conditions.

The additional selectable control on the response of the relay to differentiate fault location in terms of direction increases the level of selectivity performance and the availability of this facility again increases the level of standardisation in hardware and application.

The facility to adjust the resetting characteristic of current-operated relays means the ability to match closely the use of mixed types of solid state and electromechanical relays. In addition this facility also provides a solution to the shortcoming of solid state relays with instantaneous reset in dealing with recurrent momentary cable faults.

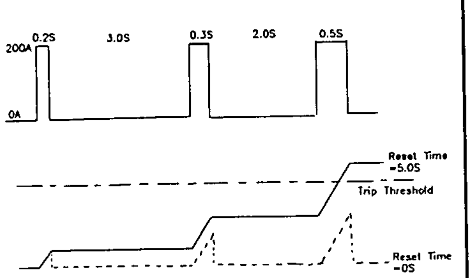


Figure 6 Recurrent Momentary Faults

Figure 6 illustrates the case of a cable fault in which the insulation breaks down, heals, breaks down again and recovers again a number of times in rapid succession. A relay with instantaneous reset characteristic will not be able to detect the fault until the latter becomes permanent. With delay reset in the resetting of the relay the cable fault will be cleared before greater damage can occur.

### Additional Facilities

Apart from improving the protection function performance, digital design of relays also enables the incorporation of a series of new facilities that include capturing of data on the relay performance and primary system conditions during system disturbances for analysis; self-monitoring to improve equipment availability; measuring capability to assist testing and commissioning; and control function to provide a coordinated or integrated approach with the protection function.

The coordination or integration of protection and control also brings into the picture the issue of communication between relays, and between relays and a central control point. Protection relays are now designed with communication capability to enable a total-system- design approach in power system protection and control.

## 4. CONCLUSION

The role of power system protection remains fundamentally the same. However the design and manufacture of protection relays are continuously changing to meet the varying application environment. From the safety point of view the requirements of quality of manufacture and design are tied to the degree of safety-critical consideration especially the issue of software validation with the increasing use of digital relays.

Notwithstanding the above there is a continuous search for better ideas, hardware to improve the performance of protection relays with more facilities to enable application and analysis of their performance and that of primary systems.

A new approach has also been evolved that links together the functions of protection and control with communicating facilities, forming a total system on a yet-to-be-standardised integration or coordination basis.

Paper No. 6

# SOCIETY'S EXPECTATIONS FOR SAFETY - CAN THEY BE MET?

**Speaker :** **Mr. Trevor Adams**
**Safety Services Manager**
**Mass Transit Railway Corporation**

# SOCIETY'S EXPECTATIONS FOR SAFETY - CAN THEY BE MET?

Mr. Trevor Adams

Safety Services Manager
Mass Transit Railway Corporation

## SYNOPSIS

Many major inquiries have recommended systems of positive safety management. These systems require the setting of clear safety policies.

The part that every person in the company must play for the policy to be achieved - must then be simply set out. The training needs should then be identified and given.

Monitoring is necessary, regularly within the management structure and also separately by independent audit.

Communication is the main task - the promotion of safety and the development of a safety culture.

Societal expectations for safety can, and indeed must, be met.

## 1. INTRODUCTION

The scene of safety management in the developed world has changed out of all recognition over the past twenty years. Major disasters before this time had led to changes in work practices and to the development and installation of new equipment and also to legislation but the tide of change is now flowing faster than ever.

It was not so long ago that in industry in Britain and similarly throughout Europe, the simple solution after a minor or serious accident was to hold the operator responsible. You would find a comment at the bottom of a report form for a system or personal accident that the individual involved had been "warned to take more care in the future" and that was the end of it.

## 2. DEVELOPMENT OF CHANGE

Major accidents in chemical and nuclear engineering in the 1970's resulted in greater attention being given to the causes and the reasons behind actions or lack of actions that had led to human or equipment failure and these had emphasised the need for the identification and introduction of control measures at design stages and also for positive systems for the management of safety.

There was only a slow and gradual general development and many industries failed to face up to the need to review their safety management systems mainly because "it had always been done that way" and also because they really believed that they did not have any safety problems that required addressing.

That belief was shattered for a number of unfortunate companies who suffered major accidents and had their lack of safety management systems exposed and commented on publicly and in the full glare of detailed media attention; and then had their lack of knowledge of such systems seen as complacency and their fault. There is now no way, with the publicity given, that any major company in a safety sensitive activity should engage in operations or carry out a major project without having carefully reviewed the methods it uses to manage safety and having ensured that it has, or is working towards methods that are, and can be demonstrated to be systematic, positive and proactive.

## 3. PROACTIVE SAFETY MANAGEMENT SYSTEMS

The requirement of a proactive safety system is to ensure a positive management system that sets standards for the control of safety, such as work procedures which includes design procedures and inspection procedures and frequencies, and then monitors and measures the extent to which these proactive management standards have been observed.

There is a need also for risks being identified and positively controlled before they become accident statistics.

### 3.1 Principles

The main principles of a proactive safety management system are:-

- a formal commitment from the top;
- the setting of procedures and clear areas of responsibility;
- training to allow people to carry out their responsibilities;
- communicating safety - both transmitting and receiving;
- monitoring to see that the responsibilities are being carried out;
- regular review.

This is little different from any management system. The management of safety must be structured in a similar manner to other management activities.

### 3.2 Policies

The setting of clear policies for safety is necessary and the commitment of the top management should be clearly set out. In United Kingdom law, there is a requirement under the Health and Safety at Work Act for such a policy statement to be made.

### 3.3 Work Instructions

There should be clear work instructions. These may be the procedures for the operation of equipment, safety rules or other written instructions. It may also be useful to identify the individual responsibilities of managers and supervisors in personalised safety responsibility statements. The statements then serve two clear purposes - as a definition of responsibility and as an auditable standard.

### 3.4 Training

There are two distinct areas of training need. The first is the conventional job or task training. This concentrates on how to carry out the job and will include safety practice and safety knowledge.

The second, also important is formal training in the management of safety and addressing issues such as:-

- safety management principles
- task analysis
- accident reporting and investigation
- purchasing and waste controls
- risk management
- hazard spotting
- auditing
- occupational health issues

### 3.5 Communications

A formal communication system based on regular safety meetings is required to allow transmission of safety related instructions, data and feedback. This system must allow information transfer - both up and down management lines, it should ensure the inclusion of safety aspects as a specific agenda item at all meetings. Meetings need also a clarification of their aims through their Terms of Reference and formalisation of minutes or meeting notes.

The best form of communication at work group level is regular formal safety communication between supervisor and supervised. In a work process that is subject to change, this could take place for a few minutes each day where the approach is discussed and safety essentials identified.

Communications is the main task - promoting safety and developing a safety culture within which every person in a company takes individual safety responsibilities seriously, they are accepted and observed.

### 3.6 Monitoring

Monitoring is the closing of the loop by the measurement of achievement of performance against defined objectives and standards.

One form of safety management system allows for two levels of monitoring and measurement.

At Level 1 is the line management monitoring, this is within the management structure and is the regular day by day supervision and inspection of activities, the scrutiny of reports and statistics and taking actions. It includes the regular pre-planned formal walkabout inspections and in offices the "signing off" or "approval" that includes checks that correct procedures have been applied in matters such as design or formulation of instructions.

The second level of control is the independent audit. This is designed to independently check that the management controls are being operated and are effective in their design. This second level will mainly concentrate on the management control systems employed at the first level and determine their effectiveness.

The audit process should be supportive and helpful - the outcome should not be just a report of good and bad points but a plan setting out the necessary improvements and a timescale with auditable milestones. There must be assistance to the manager in solving the problems and finding solutions.

### 3.7 Climate Of Awareness

A Safety Management Programme cannot be just a series of events and actions. They must be related and have a common purpose and that is to instil or enhance a climate of safety awareness so that for every member of staff, safety is paramount and safety considerations are fully in mind in whatever task we are involved.

### 3.8 Risk Analysis

The use of risk analysis techniques in proactive safety management is important and is an increasingly essential element of planning for new systems, for safety assessments of present operations and for identifying priorities for safety expenditure. The benefits of such approaches are wide and it is of interest that in the United Kingdom draft legislation has been prepared that requires risk assessment to be carried out of work processes. There is also a European Community Directive requiring risk assessment and for large assessments to be written up in the form of a Safety Case. The Safety Case identifies the risks and it must also identify the steps taken to control the risks.

### 3.9 Summary

Each of us would agree that society's expectations must be met, one difficulty may be in defining those expectations.

In Hong Kong, in 1991, there were nearly 88,000 occupational accidents - of which 245 were fatal (1). What are the expectations of society? Some measures are taken to punish or to enforce but there is no great outcry from society in general at those accident statistics. Those attending this conference however, are part of society and it is our expectations that should drive the matter. Safety does not just happen, it must be worked at and with positive policies for managing safety, the expectations of society for safety can be met and those expectations also far exceeded.

Note:- (1) Hong Kong 1992 - Government Information Service

Paper No. 6

Paper No. 7

# NUCLEAR POWER AND ITS IMPLICATIONS ON PUBLIC SAFETY IN HONG KONG

Speaker : Dr. Raymond Yeung Mankit
Lecturer
Department of Mechanical Engineering
The University of Hong Kong

## 2. SOURCE TERMS

The source term is the quantity, timing and characteristics of the release of radioactive material to the environment following a severe reactor accident. This is an accident in which fuel is damaged by overheating to the point of substantial escape of fission products to the containment from the fuel and the containment building has not functioned adequately to prevent its breaching and the escape of significant amounts of radioactivity to the environment. According to the chemical properties, radioactivities inside a nuclear reactor can be roughly placed in three categories:

1) Fission gases (Xe, Kr)

2) Volatile materials (Br, I, Te...etc)

3) Non-volatile materials (Mo, Rh...etc).

The earliest reference to reactor accident release can be traced back to the 1950 WASH-3 report [2] which used arbitrary assumptions to assess the hazard. Similar approaches were used in later studies such as WASH-740 [3] and TID-14844 [4]. Later, the 1974 U.S. Nuclear Regulatory Commission (USNRC) Reg. Guide 1.4 [5] required 100% of the total inventory of fission gases and 25% of the iodine inventory should be assumed to be immediately available for leakage from the containment in a Loss-of-Coolant-Accident (LOCA). In 1975, a more systematic quantitative risk assessment was carried out by Rasmussen and reported in WASH-1400 [1] in which all accidental releases of the radionuclides were classified into 9 release categories for PWRs and 5 release categories for BWRs. In the period following the Three-Mile-Island accident in 1979, the U.S. Nuclear Regulatory Commission (NRC) began a major effort toreview existing U.S. nuclear power plant designs and the regulatory use of improved source terms [6]. In 1987, this effort resulted in the issuance of NUREG-1150 [7] which describes the results of detailed plant-specific PSAs performed for five U.S. plants and their source terms. In 1988, U.S. NRC required all utilities to perform Individual Plant Examinations (IPEs) to identify the severe accident vulnerabilities in their plants [8]. Since a plant-specific Probabilistic Safety Analysis (PSA) has not been intended for Daya Bay Station, any risk study by Hong Kong is, to a large extent, only be limited to the offsite consequence analysis with generic source terms adopted from the U.S. or other studies.

## 3. ATMOSPHERIC DISPERSION

Radioactivities released to the atmosphere are transported away from the point of release and dispersed through atmospheric processes. In order to determine the dilution factor, an atmospheric dispersion model has to be used. Reviews performed by earlier workers such as Hoffman [9] and Turner [10] have indicated that most researchers have used the Gaussian form of solution. In fact, the Gaussian model has been adopted as a standard method in regulating both radioactive (USNRC, 1977; IAEA, 1980) and other airborne species (USEPA) [11]. The Gaussian models also are the most extensively validated class of diffusion models, and their behaviour, including their shortcomings, is relatively well known.

In the Gaussian model, functional relationships for the atmospheric dispersion are derived by assuming that it is governed by the classical Fick's Law diffusion equation. To obtain reasonable results, the solution must be used in conjunction with coefficients of diffusivities which are functions of both space and climatic conditions. For a moving coordinate travelling with the plume, the local radionuclide concentration is given by [12]:

$$\frac{\chi}{Q} = \frac{(2\pi)^{-3/2}}{\sigma_x\sigma_y\sigma_z} \exp - \frac{1}{2}\left[ \frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2} + \frac{h^2}{\sigma_z^2} \right] \tag{2}$$

where $\chi$ - local concentration

$Q$ - released radionuclide quantity

$h$ - effective stack height

$\sigma_x, \sigma_y, \sigma_z$ - diffusion coefficients in x, y, z directions.

Obviously, the diffusion coefficients are very important inputs to the Gaussian model. Pasquill suggested a practical scheme for the estimation of diffusion coefficients for different stability classes [13]. Also, Cramer [14] assumed power laws for the diffusion coefficients and obtained best fits to the Prarie Grass and Round Hill diffusion data. For the situation of Hong Kong, the relatively large distance between Daya Bay station and Hong Kong should provide substantial dilution under most circumstances but uncertainties arise from the relatively complex terrain and the sea/land setting of the region.

## 4. METEOROLOGICAL CONDITIONS

In order to determine the atmospheric dispersion dilution factor, local meteorological data, such as wind direction, wind speed and atmospheric stability condition must be known and used as inputs. From historic data, it can be seen that the Hong Kong wind rose is dominated by the east and north-east-east directions most of the year. In the spring, the wind is usually north-easterly blowing from Daya Bay to Hong Kong. During the summer months of July and August, the wind direction shifts to become south-westerly. Although the wind rose for a particular year may vary, the average wind rose over a reasonably long period should be quite representing.

The dispersion of radioactivities released from a postulated nuclear accident depends on the weather from the start of the accident through a period of tens to hundreds of hours following the accident. The weather conditions determine the transport and dispersion processes and thus, the magnitude of the consequence that will result.

In addition to the dispersion, there are two depletion processes that tend to reduce the downwind concentration. For short half-lived radionuclides, the radioactive decay during flight can cause a significant reduction in the concentration. On the other hand, radionuclides except the fission gases may be removed either by gravitational settling or by washout by rain. The deposition processes reduce concentration in the atmosphere but increase ground contamination.

## 5. HEALTH EFFECTS

The radiation doses resulted from an accidental release of radioactivities can be divided into two categories: early exposure and chronic exposure. Early exposure occurs during and shortly after the plume passage and chronic exposure takes place over a relatively long period.

For an individual downwind from the point of release, there are three pathways contributing to the early exposure:

(i) cloudshine - direct external exposure to the radioactivities of the passing cloud,

(ii) groundshine - exposure to the radioactivities deposited on the ground,

(iii) inhalation of radionuclides from the cloud.

There are three pathways contributing to the long term chronic exposure; they are:

(i) long-term exposure to ground contamination,

(ii) long term irradiation from inhaled radionuclides,

(iii) ingestion of contaminated food.

For a given accident, it is obvious that the early exposure strongly depends on the distance of the individual from the point of release, the weather conditions and the form of sheltering. On the other hand, the chronic exposure is more controllable and can be mitigated by proper emergency countermeasures to some extent.

Health effects are generally classified into two categories: 1) early effects and 2) latent effects. Early effects include early fatalities and early injuries. Early fatalities are determined on the basis of acute radiation exposure to the bone marrow, lungs, and gastro-intestinal tract (GI tract). Early injuries are those radiation induced illnesses requiring medical attention or hospital treatment and they are determined on the basis of early exposure to stomach, lung and thyroid. The risks of all early effects can be estimated by the following risk curve [15]:

$$r = 1 - \exp(-H) \qquad (3)$$

where

$$H = \ln(2) \cdot \left( \frac{D_{eff}}{D_{50}} \right)^{\beta} \qquad (4)$$

$D_{eff}$ - effective organ dose

$D_{50}$ - 50% casulty dose

and $\beta$ - shape factor

Also, the early effect risks are not observed below their threshold doses. Based on available data, it is known that dose delivered to the bone narrow is the major contributors to early fatality because of its relatively low threshold dose. However, the early fatality risk can be reduced somewhat if more supportive medical treatment is available.

Latent effects are primarily latent cancer of various kinds. For latent cancers, the individual risk is low and population dose is generally used to estimate the expected incident latent cases in a statistical manner. The major cancer types of concern include Leukemia, Bone Cancer, Thyroid Cancer (incidence and death), Lung cancer (incidence and death) and GI-Tract Cancer (incidence and death).

The latent cancer incidence is generally characterized by a latent period (from 2 to 10 years) and an incident period. Since the latent cancers are not solely caused by the early doses, the internal organ doses due to continuous irradiation from the inhaled radionuclides also contribute to the latent cancer incidence. Empirical data of latent cancer risk factors were primarily derived from the continuous observation of WWII atomic weapon victims. Earlier research works suggested that there is a plateau period for latent cancer incidence but more recent studies tend to believe that there is no cutoff of the plateau period and the incidence of some cancers will persist throughout the life spans of the affected population [15].

## 6. POPULATION AND HOUSING

According to the 1991 Hong Kong census [16], the total population of Greater Hong Kong is 5,511,149 with most of the population concentrating in Hong Kong Island and Kowloon. A population distribution is shown in Table 1. It can be seen that Kwun Tong (45 km from Daya Bay) has the highest population of 564,258. The second most populated area is Eastern (48 km from Daya Bay) with a population of 543,889. The population centre closestto the Daya Bay plant is Sai Kung which has a population of 127,027.

Comparing the 1991 Census with the 1986 Census, one can easily find that the total population increase of Hong Kong is relatively small. However, this can be misleading because there is a significant population redistribution from older districts to the "new towns" in the New Territories. For example, populations in Kwun Tong, Yau Tsim/Mong Kok/Sham Shui Po and Kowloon City today are less than what they were in 1986 but new towns such as Sha Tin, Tai Po, and Sai Kung register increases of 39%, 42% and 184%, respectively. The shift of population to the new towns in the north-eastern part of Greater Hong Kong tends to increase the overall

Table 1 Hong Kong Population Centres

| | Centre | Distance from Daya Bay | Population |
|---|---|---|---|
| 1 | Central/Western | 54 | 245,524 |
| 2 | Southern | 55 | 250,866 |
| 3 | Eastern | 48 | 543,889 |
| 4 | Wanchai | 52 | 173,974 |
| 5 | Yau Tsim | 50 | 108,051 |
| 6 | Mong Kok | 49 | 165,430 |
| 7 | Sham Shui Po | 49 | 369,951 |
| 8 | Kwai Tsing | 51 | 430,852 |
| 9 | Tsuen Wan | 50 | 264,448 |
| 10 | Kowloon City | 48 | 389,839 |
| 11 | Wong Tai Sin | 45 | 377,736 |
| 12 | Kwun Tong | 45 | 564,258 |
| 13 | Sai Kung | 42 | 127,027 |
| 14 | North | 43 | 162,067 |
| 15 | Tai Po | 43 | 197,691 |
| 16 | Sha Tin | 44 | 494,270 |
| 17 | Tuen Mun | 63 | 373,366 |
| 18 | Yuen Long | 55 | 225,278 |
| 19 | Islands | 67 | 46,632 |
| | | Total | 5,511,149 |

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risk of the society because of their relatively shorter distances from the Daya Bay station.

It is a common practice for most nuclear accident consequence study to evaluate the early doses directly from the cloud and the radionuclides deposited on the ground surface. In an urbanized setting such as Hong Kong, it would be reasonable to assume that most of the population remain in some form of housing which provides shielding effects from the deposited activities of ground surface, outer walls and roofs of buildings. In general, high-rise buildings provides the best shielding and temporary structures gives the least protection for external gamma irradiation. For inhalation doses, this is not as straight forward and the protection depends entirely on the ventilation of the building. Obviously, a centrally air-conditioned office building would give much better protection than a well-ventilated residential building. To order to determine the population doses more accurately during a nuclear accident, the shielding and inhalation factors of various types of building and the numbers of their occupants in different times of the day.

## 7. PSA STUDIES IN HONG KONG

In 1978, USNRC issued NUREG-0396 [17] which first introduced the concept of Emergency Planning by establishing the 10-mile (16 km) Plume Exposure Pathway Emergency Planning Zone (EPZ) and the 50-mile (80 km) Ingestion Exposure Pathway EPZ. Similar measures have been implemented in many European nations with a variety of EPZ sizes but all of them are smaller than those of the U.S. Obviously, Hong Kong is clearly outside the Plume Exposure Pathway EPZ by any standard and evacuation of population is not the appropriate option during emergency. Instead, emphasis should be placed on the mitigation of the consequences by the implementation of proper emergency countermeasures.

After the unfortunate occurrence of the Chernohyl accident in 1986, the Hong Kong government hired the United Kingdom Atomic Energy Authority (UKAEA) as the consultant and the first consultancy report [18] was released in 1987 providing the guidelines for emergency planning for Hong Kong and some preliminary estimate for individual radiation doses. In 1990, additional calculations were performed by UKAEA and the risks of the accident consequences for Hong Kong were given in a second report [19]. During this time, an alternative independent study was conducted at the University of Hong Kong (HKU) by using a novel two-dimensional plume trajectory dispersion/consequence model RADIS [20]. A comparison between the HKU and UKAEA studies on the occurrence frequencies for various accident consequences was made and it was found that the UKAEA results were actually quite conservative [21]. The HKU study also found that rainy conditions enhances groundshine radiation and increases the risk of early fatality and injury. It was also found that dry weather conditions tend to retain the radioactivities in the atmosphere thus enhancing the long term internal doses due to inhalation. This implies that rainy conditions are more likely to cause more early effects while the public are more vulnerable to latent effects under dry conditions [20]. In addition, the HKU study also investigated the shielding effects of the buildings and found that the protection provided by the buildings can practically eliminate the risk of early fatality under any circumstance. On the other hand, the determination of the risk associated with contaminated food is still relatively uncertain. This is because the typical Hong Kong dietetic pattern is completely different from those of the west and the lack of nuclear/biological data for some of the produces and fishes will probably remain as a problem for some time to come.

## 8. SUMMARY AND CONCLUSIONS

The present paper has presented the general methodology of quantitative risk assessment and the governing factors affecting the offsite consequences for a nuclear power plant. Even though the actual risk of Daya Bay Station cannot be determined until a comprehensive plant and site specific Probabilistic Safety Analysis is performed, progresses have been made by the Hong Kong University in the areas of offsite accident consequence analysis and its comparison with the UKAEA study. The results of the HKU study has also provided the approximated risk levels of various accident consequences and the relative importances and benefits of the controlling factors such as weather conditions, population distribution and the building effects. This kind of information is absolutely necessary for the development of a successful emergency plan and the implementation of proper emergency countermeasures in a timely manner.

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Paper No. 8

# ELECTRICAL FIRE SAFETY AND PROTECTION

Speaker : Mr Richard Lo Ching-Wai
Deputy Chief Fire Officer
Fire Protection Bureau
Fire Services Department

# ELECTRICAL FIRE SAFETY AND PROTECTION

Mr. Lo Ching-wai

Deputy Chief Fire Officer
Fire Protection Bureau
Fire Services Department, Hong Kong

## SYNOPSIS

Fire hazards associated with electrical installations and equipment are not always clearly covered by rules and regulations, and are often overlooked by engineers.

Approximately 20% of building fires in Hong Kong in the past four years were of electrical origin. Electrical faults were amongst the three major known fire causes following overcooking and a bit more than careless disposal of smoking materials. Improper and inadequate maintenance of electrical installations and equipment is believed to be the major cause of these fire outbreaks. Properly designed and maintained electrical installations and equipment are essential for electrical fire safety and in turn would reduce the incident of fire due to electrical origin.

As an extinguishing media, water is always the most effective and cheapest extinguishing agent for fires. Different types of fire extinguishing systems using water have been developed for special applications. In Hong Kong, the concept of using water to protect electrical installations and equipment has gradually been accepted by electricity supply companies, the developers and equipment owners.

## 1. INTRODUCTION

In Hong Kong, electrical faults were one of the major causes of fire outbreaks in buildings, and were also the major concern of the Fire Services Department in promoting the awareness of fire safety and prevention in buildings. In overseas, a survey by the Fire Protection Association in collaboration with the Joint Fire Research Organisation over the years for which fire reports were available also showed the following items were the causes of large fires in the order given:

a. Electrical installations and apparatus;

b. Malicious or intentional ignition;

c. Smoking materials

and that these three causes accounted for 75% of the total damage where the cause could be established.

This paper summaries the various causes of fires in different types of buildings in Hong Kong in the year 1991, and the main causes of fire due to electrical origin based on the previous fire incident investigations. The paper also briefly describes various types of automatic fire fighting systems for the protection of electrical equipment and installations, in particular, the systems using water as an extinguishing agent.

With the recent enactment of the Electricity (Wiring) Regulations, it is expected that the standard of the design, installation and maintenance of electrical installations will be improved and, as a result, the fire outbreaks due to electrical faults will also be diminished.

## 2. FIRES OF ELECTRICAL ORIGIN

Overcooking, faults in electrical installation and apparatus, and careless disposal of smoking materials are the three major causes of fires in Hong Kong. In 1991, fires of electrical origin caused 1,222 accidental fires in buildings out of the total building fire calls of 6,393. The other two major causes of fires, namely overcooking and smoking materials, accounted for 2,323 and 929 cases respectively.

Amongst these 1,222 fires of electrical origin, 594, 450 and 178 incidents respectively occurred in domestic, commercial and industrial buildings. In private domestic buildings, apart from overcooking in kitchen, fires of electrical origin accounted for nearly 19% of the total fire incidents. The electrical installations in domestic premises of housing estates seemed to have been better maintained. There were only 110 incidents due to electrical origin out of 1,908 cases. In private commercial premises, it

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represented more than 51% of the total. In general restaurants, apart from kitchen fires, fires of electrical origin was also the major cause. The electrical installations in institutional buildings and Government quarters were neither better off, electricity related fires were major causes of fires in these buildings. Statistics for the various causes of fires in 1991 are shown in Table 1.

In comparison with other causes, fires of electrical origin resulted in the highest number of public injury and fatality. In 1991, there were 78 public injuries due to electrical fires out of the total of 456, and the number of fatalities was 5 out of 36. During this same period, the other two major causes of fire, i.e. smoking materials and overcooking had caused no fatality. Summary of the injuries/fatalities numbers due to fires in 1991 are shown in Table 2.

From these statistics, it can be seen that fires of electrical origin were the major cause of property and life damages in buildings.

## 3. CAUSES OF ELECTRICAL FIRES

Summarised below are the three main causes of fire of electrical origin together with some common examples from previous fire incident investigations :

### 3.1 Overloading And Faulty Installations That Cause Overheating

a. Abnormal or excessive temperature rise on the surface of electrical cables and switchgear. This indicates that the circuit is carrying a current exceeding its designed capacity.

b. Loose connections on cable junction, termination points, switches, sockets and plugs. These cause local overheating.

c. Improper cable joints along cable routes. These also cause local overheating.

d. Reduction of cable strands at junction or termination points. This causes both overloading and overheating.

e. Protective gears over-rated. The common malpractice is the replacement of fuse by bare link or conducting wire without considering its current rating.

### 3.2 Dangerous Practices

a. No protective conductors connected to 3-pin plugs or socket outlets. This creates electrical shock and fire hazards.

b. Adaptors in use for fixed appliances. This common practice creates fire hazard where combustible materials are in close proximity to the socket.

c. Cables passing through smoke lobby. PVC insulation of unprotected cables produces heavy toxic fumes/smoke in the event of overheating/fire.

d. Compartment not properly sealed at points where cables pass through walls or floors.

### 3.3 Hazards Resulting From Poor Maintenance

a. Moisture accumulation on the surface of electrical appliances and switchgears. This may be caused by condensation or water dripping as a result of weather effects or cooking.

b. Mechanical damage on cable insulation. This creates fire hazard if the conductor is exposed.

c. Cable aging. The symptoms are cracking, discolouring, hardening of insulation which indicates that the cable has deteriorated and requires replacement.

Apart from the above three main causes of electrical fires, there is another important fire safety measures in buildings which are often overlooked by the workers / contractors. Buildings, no matter old or new, are full of openings, of various sizes, and existed for a variety of reasons. The electrical services, in the form of cables, busducts, trunkings, etc. have to pass from one fire compartment wall or floor to another, and therefore penetrate through fire barriers enclosing the designed compartments. Since electrical services penetrating through walls or floors never fit exactly into the holes provided for them, there are always gaps left behind. These gaps, in most cases are either forgotten or patched up with unsuitable materials. Accordingly, the designed integrity of the walls or floors are breached. Fire and smoke will spread through these compartments and floors via such gaps or holes and can cause extensive damages to property or life. Therefore, all gaps and holes left behind by the electrical services through the fire barriers must be suitably sealed to maintain the designed integrity of the barriers.

## 4. FIRE SAFETY OF ELECTRICAL EQUIPMENT AND INSTALLATION

In some industrial undertakings where there are the likelihood of the presence of volatile flammable liquids or flammable gases required to be used or handled in specific processes, the use of electrical equipment or installations that may produce an arc or spark would have to be housed in spark-proof enclosures.

Typical examples of these areas are the dangerous goods stores for flammable liquids or gases, operating theatres in hospitals, etc. Design engineers should therefore pay particular attention during the design, installation and testing stages to ensure that they would not release sufficient electrical energy under both normal and abnormal conditions to cause ignition to a specific hazardous atmospheric mixture.

## 5. RULES AND REGULATIONS FOR FIRE PROTECTION

Under the current Code of Practice for Minimum Fire Service Installations and Equipment, the safety requirements for electrical equipment in buildings comprise of:

a. Automatic actuating devices as required by the equipment which needs to be automatically actuated;

b. Automatic fixed installation other than water (for oil-filled transformer rooms with capacity in excess of 1,500 kVA);

c. Fire detection system for areas not covered by automatic fixed installation; and

d. Portable hand-operated fire extinguishers.

## 6. GAS FLOODING SYSTEM

This is an automatic fixed installation discharging an extinguishing gas into the protected area to suppress the fire. In the past, this gas flooding system using carbon dioxide or halon was commonly used for electrical equipment room and computer room. However, carbon dioxide gas flooding system had in several cases caused injuries in the past. When it was accidentally discharged, the workers therein could be suffocated by its high concentration volume. Halon which is non-toxic, inert and requires a much lower concentration due to its inhibitory factor had substituted the use of carbon dioxide in the past ten years as the most popular and effective agent for suppressing electrical fires. However, due to the ozone depletion nature of halon, its use in fire fighting has now been restricted to certain essential uses only. Up to present, proven substitute for halon for fire fighting is still not yet available for commercial use.

## 7. SPRINKLER SYSTEM

Water is the most effective extinguishing agent for most common types of fire. Sprinkler system using water is a mandatory fire protection installation for all non-domestic buildings in Hong Kong. Unlike gas flooding system, sprinkler system will not flood the entire room with water when actuated. Water will only be discharged from those sprinkler heads which are actuated by the heat of fire or smoke, and fires will normally be extinguished by not more than three actuated sprinklers. Moreover, water damages will not be as serious as most people envisage.

## 8. PRE-ACTION RECYCLING SPRINKLER SYSTEM

This is a special type of sprinkler system. In normal circumstances, the system is not filled with water. Water will only flow into the system on actuation of a special type of heat detector. Water will only be discharged if the sprinkler head is also actuated by the heat of the fire. This eliminates any accidental discharge of water due to system malfunction or mechanical damage to the pipework and sprinkler head. When the fire is extinguished by the water discharged from the sprinkler head, temperature drops and the heat detector will shut off the water flow which minimizes the water damages.

Nowadays, this sprinkler system is, commonly used for protecting precision electrical equipment and installations, e.g. computer, telecommunication suites, etc.

## 9. HIGH PRESSURE WATER SPRAY SYSTEM

The term 'water spray' refers to the use of water in a form having a predetermined discharge pattern, water particle size, velocity, and density discharged from specially designed nozzles or discharge devices. Water spray system is usually applied to the protection of premises/equipment having a special hazard. The protection can be specifically designed to provide an effective fire control, extinguishment, prevention, and/or exposure protection.

The system is a specially designed fixed pipe system connected to a reliable source of water supply, and equipped with water spray nozzles for specific water discharge and distribution over the equipment surface or area to be protected. The piping system is connected to the water supply through an automatically or manually actuated valve which initiates the flow of water. An automatic valve is actuated by operation of the automatic fire detection equipment installed in the protected areas.

Water spray systems are most commonly used to protect equipment including high voltage transformers, cable chambers, motors etc. Power companies in Hong Kong have already widely adopted this system in the protection of their substations.

## 10. LOOKING AHEAD

Prior to the enactment of the Electricity Ordinance Cap. 406 Laws of Hong Kong on 1.6.1992, when an electrical installation in a new building is completed, it will be inspected and tested by the relevant Power Company to ensure compliance of various wiring regulations before the system is energized. Unfortunately, a lot of fitting-out, alteration and additional work on the electrical installation and apparatus will have to be made after the building has been occupied. Perhaps due to the ignorance of many installation owners, they often happened to engage some unauthorized or incompetent contractors/ workers, who without knowing the detail design of the system, may then incorporate some installations which may overload the original system. Though there were standing instructions from the Power Companies for the report of any additional loads to systems, yet it is not uncommon that some contractors ignore such stipulated requirements. As a result, fire hazard may then arise as proper inspection and testing have not been conducted on these alterations.

Since the Electricity (Wiring) Regulations under the Electricity Ordinance Cap. 406 Laws of Hong Kong was enacted on 1 June 1992, all fixed electrical installations in buildings would have to be designed, installed, altered or repaired and certified on completion by Registered Electrical Workers and Contractor in accordance with the requirements laid down in the Regulations.

Furthermore, the fixed electrical installations exceeding certain capacity have also to be inspected, tested and certified periodically. The introduction of this self-regulating and certification system is a major step on the improvement of the safety of electrical installations in Hong Kong.

## 11. CONCLUSION

With the huge infrastructure project proceeding, the economy of Hong Kong will certainly continue to grow towards the years 2000 and beyond. Likewise, the electricity consumption and the electrical installation industry will also grow with the same pace. I would assume that engineers would pay more emphasis on fire safety in respect of the design, installation and maintenance of electrical installations in buildings.

Economy in electrical installations is definitely false economy. Use of adequate wiring and good quality electrical equipment will more than repay any extra cost by ensuring safe operation without fire risks.

Adequate provision of fire service installations to protect electrical installations can suppress the fire at the very beginning and will accordingly limit the extent of damages caused. In order that a safe environment for the occupants can be ensured, properly designed and maintained electrical installations and equipment are absolutely essential for electrical fire safety which in turn would reduce the incident of fire due to electrical origin.

TABLE 1 : Statistics of Various Causes of Fires in 1991

| Building type | | Cause: Electrical | Overcooking | Cigarette | Others | Unknown | Total |
|---|---|---|---|---|---|---|---|
| Domestic Buildings | Domestic (Private) | 421 | 1,198 | 191 | 394 | 15 | 2,219 |
| | Domestic (Housing Est.) | 110 | 1,056 | 321 | 406 | 15 | 1,908 |
| | Domestic (Squatter) | 48 | 16 | 26 | 48 | 14 | 152 |
| | Temporary Housing Area | 5 | 11 | 15 | 8 | 11 | 50 |
| | Government Quarter | 10 | 10 | 5 | 2 | 0 | 27 |
| | Sub-total | 594 | 2,291 | 558 | 858 | 55 | 4,356 |
| Commerical Buildings | Commercial (Private) | 311 | 16 | 74 | 195 | 12 | 608 |
| | Commercial (Housing Est.) | 9 | 2 | 8 | 19 | 1 | 39 |
| | Restaurant | 44 | 7 | 11 | 162 | 2 | 226 |
| | Place of Public Amusement | 18 | 0 | 55 | 59 | 8 | 140 |
| | Institutional Building | 41 | 3 | 14 | 38 | 9 | 105 |
| | Commercial (Squatter) | 27 | 2 | 48 | 49 | 15 | 141 |
| | Sub-total | 450 | 30 | 210 | 522 | 47 | 1,259 |
| Industrial Buildings | Factory in Domestic | 1 | 0 | 0 | 1 | 0 | 2 |
| | Government Factory | 3 | 1 | 3 | 5 | 0 | 12 |
| | Private Factory | 140 | 1 | 86 | 136 | 23 | 386 |
| | Factory in Squatter | 0 | 0 | 0 | 0 | 0 | 0 |
| | Construction Site | 34 | 0 | 72 | 80 | 12 | 198 |
| | Sub-total | 178 | 2 | 161 | 222 | 35 | 598 |
| Total | | 1,222 | 2,323 | 929 | 1,602 | 137 | 6,393 |

TABLE 2 : Statistics of Injuries/Fatalities Against Various Causes of Fires in 1991

| | Electrical | Overcooking | Cigarette | Others | Total |
|---|---|---|---|---|---|
| Injuries | 78 | 0 | 48 | 330 | 456 |
| Fatalities | 5 | 0 | 0 | 31 | 36 |
| Total | 83 | 0 | 48 | 361 | 492 |

Paper No. 9

# ELECTRICALLY SICK BUILDINGS SYMPTOMS, DIAGNOSIS AND TREATMENT

**Speaker : Mr. W.H. Wong**
**Director**
**BMP Mechanical and Electrical Ltd**

# ELECTRICALLY SICK BUILDINGS
# SYMPTOMS, DIAGNOSIS AND TREATMENT

Mr. W.H. Wong

Director

BMP Mechanical and Electrical Ltd

## 1. INTRODUCTION

When a fire breaks out in a building, the cause is very often due to a faulty electrical installation. This paper is not to discuss how true is this statement but it is very true that an electrically sick building can cause fire.

Most people are readily aware of the obvious fire hazard possibly resulted from a problem electrical system. What they do not realise are that there are many more other hidden risks.

The unexpected early visit of heavy rain in the beginning of this summer had caused serious flooding to a number of buildings and the problem had been due to or amplified by the malfunction of basement sump pumps.

A few years ago, a cleaner trying to clean a new building prior to its opening fell off from the gondola and died. The reason was the wrong phase connection of the power supply and as a result the suction fans which supposedly kept the gondola firmly at the building facade became blowers hence toppling the gondola over.

Interruption of water supplies to high-rise buildings, trapping of people inside lifts, or lifts travelling right down to the bottom of lift shafts etc. are often caused by faulty control switches and/or wiring.

These are in fact quite natural though, as all engineering services in a building are dependent on the proper function of the electrical installation. In fact, some structural engineers are of the opinion that cracks in structures of buildings are sometimes caused by rusty electrical conduits cast in structures. So an electrically sick building may, to the extreme, cause structural problems.

It is apparent that electrically sick buildings can cause inconvenience and be harmful to occupants. The sickness must therefore be identified, cured and prevented.

## 2. WHAT IS AN ELECTRICALLY SICK BUILDING?

The term 'electrically sick building' in this paper should not be confused with sick building syndrome (or building related illness) which refers to a series of symptoms suffered by building occupants caused by unhealthy environment of the buildings. The 'electrical sickness' is a term particularly introduced for the sake of this paper which would address the symptoms of the sickness, the cause, how it can be cured and the prevention. In simple words, a sick electrical installation is one with problems which result in inconvenience to occupants, limit the use of the building, reduce the flexibility of changes, damage the building and can even cause injury to users and occupants.

An electrical installation can be sick at any parts of the system; including:

- the supply capacity
- the distribution system (main switchboards, busducts, cables, distribution boards, etc.)
- the earthing system
- the wiring system
- the control wiring for plants and equipment of air conditioning, mechanical, plumbing and drainage systems

A building needs not be old to become sick. Electrical installations of new buildings can also be sick, although old ones tend to get sick more easily and more seriously.

## 3. SYMPTOMS

There are in fact not too many obvious symptoms in electrically sick buildings. They can be concluded in the following items.

### 3.1 Frequent Interruption Of Supplies

This can be further classified to particular circuits of a system or the main incoming supply.

The former case is often due to faults of the circuit, either the conductors or components of the circuit, or the circuit has been overloaded. Problems of this nature are comparatively minor and can be easily identified and resolved. However, some operators can still overlook this obvious symptom particularly with the use of MCCB's and MCB's as interrupted circuits can be conveniently reset.

The latter case would be mostly due to the fact that the supply cannot meet with the demand of the system. The cause of this is of a much more complex nature and the solution is always difficult.

### 3.2 Overheating Of Electrical Components

This symptom can be found in different parts of an electrical system including:

- Main Switchboards in particular busbars and switchgears
- Rising mains including busbar trunking, busducts or cable risers
- Distribution cables and small wiring

This symptom is not easily noticed and is difficult to be identified. Even very experienced technicians or engineers cannot be certain whether switchgears or conductors are operating at excessively high temperatures by visual inspections.

Very often, not until the conductors become darkened, insulation materials start to melt or components get obviously discoloured; people would not realise that there have been overheating problems in the system.

The use of infra-red thermographic survey to identify hot spots of an electrical system is an effective means. This however may be considered costly and unnecessary to a lot of operators.

### 3.3 Electric Shock

This is an obvious symptom to users and this can be because of insulation failure, the omission or disconnection of protective conductors or the malfunction of circuit breakers. This happens particularly more often to older installations which were designed and installed prior to the implementation of the latest wiring regulations which have more stringent control on protection against electric shock.

### 3.4 Difficulty In Operation And Maintenance

This is a common problem encountered by a lot of building management people. This can be the result of improper spatial planning of the electrical plant, unavailability of spare parts of outdated and obsolete equipment, or inadequate design consideration of switchgears and equipment for servicing, expansion and maintenance.

### 3.5 Interference

Sophisticated electronic equipment and computers depend on a clean power supply for their proper function. The growth in the use of this type of equipment demands the electrical installations to have little interference even for non-purposed-built buildings. To these users, a power supply with high voltage distortion and electrical noise is a sickness in the electrical system.

## 4. CAUSE AND DIAGNOSIS

There are many factors that lead to illness of an electrical installation. The major ones include:

### 4.1 Increase In Demand

Lives of quite a number of buildings in Hong Kong are very short. It is not uncommon that buildings about 10 years old are knocked down and redeveloped again. Nevertheless, the pace of the growth of electricity demand is even faster.

The increase in electricity demand in buildings in the last twenty and even thirty years has been rapid. This happens virtually in all types of buildings including:

- Residential Buildings -
  due to the change in life style, the growth in the use of electrical appliances in particular air conditioners is exponential

- Industrial Buildings -
  due to the change from labour intensive industries to sophisticated manufacturing process and due to workers' higher expectation of working environment, a lot of industrial buildings now require air conditioning

- Office Buildings -
  due to the extensive application of electronic office equipment and appliance, greater electricity supply which results in greater air conditioning load and in turn greater electricity demand, is required.

- Commercial Complexes-
  due to the increase in density of shoppers demanding more conditioned air and the change of life style of average people (more and more people tend to dine out) boostering the growth of F&B outlets and restaurants in commercial complexes; both increase the electricity consumption substantially

In fact, in addition to these, even institutional buildings such as schools, university campus and hospitals are now partially or fully air conditioned while in the past, they would only be fitted with ceiling fans.

While there are no rigid regulations with regard to the design parameters of electricity demands for various buildings, the common practice in Hong Kong can be summarised as below:

| | Unit Load | | |
|---|---|---|---|
| Type of Bldg | In the 70's | In the 80's | Now |
| Residential flats of average size (40 - 60m2) | 1.75 - 2KVA each | 2.5 - 3 KVA each | 3.6 KVA each |
| Flatted industrial VA/m2 buildings | 180 VA/m | 2200 VA/m | 2220 |
| Office buildings VA/m2 | 100 VA/m | 2130 VA/m | 2150 |
| Commercial complexes VA/m2 | 180 VA/m | 2200 VA/m | 2230 |

These figures reflect an average growth of over 35% in twenty years.

This problem is further worsened by the change of use of buildings. It is common that some industrial buildings (and even godown buildings) are now used as offices, offices can be used as shops and restaurants, and even car parks are changed to commercial shops and restaurants. The change of use usually is a virus causing the most difficult sickness in the electrical system of buildings hard to be cured.

## 4.2 Substandard Materials And Equipment

This is a very usual cause of the problem. The use of substandard electrical products can be found in different parts of an installation. Some of the particular concerns are highlighted below:

### Main Switchboards

A lot of switchboards in existing buildings were designed and fabricated without compartmentation. This would make inspection, servicing, maintenance, modification, extension and upgrade difficult and risky.

Switchboards with compartments but not properly designed and constructed could be even worse. Three years ago, two electricians working on a switchboard were seriously hurt by an explosion. An investigation revealed that there existed a gap between two compartments of the switchboard and although the section being serviced was switched off, a tool accidentally dropped into the switchboard through this gap had short-circuited the main bars of two phases resulting in an explosion. Both electricians were seriously burnt at the face, hands and the body. One of the two victims of the 'sick' switchboard required hospital treatment for over one year and probably could never be 100% recovered.

The other common problem in switchboards is the poor workmanship of the busbars particularly at the joints. Hot spots often occur at these locations and as a result generate extra heat and raise the temperature of the switchboard to beyond the design operating temperature. Switchgears and components operating continuously under this condition would be quickly deteriorated and would have a much shorter life.

### Switchgears

The improper selection of switchgears is another common source of sickness. A lot of switchgears manufacturers have their products operating capacities defined at an 'open' environment or an ambient temperature much lower than the tropical conditions. These switchgears when installed inside an enclosed cubicle type switchboard or used inside an enclosed switchroom or riser duct would be overloaded if the 'derating factor' is not suitably applied.

### Busbar Risers

Many buildings were fitted with locally made busbar risers. This type of risers is not necessarily substandard. However, risers not properly designed and assembled (i.e. not built in accordance with a fully type-tested design) may not be well balanced and not rigidly assembled and as a result vibration at the busbars would occur. In times, busbar joints and tee-off's would get loosened hence forming hot spots, damaging the supports and insulations, and finally short-circuiting the busbars.

Even proprietary busducts can have very short lives. The probable reason is the poor site conditions when they were installed. Very often, because of the tight construction programme, busducts need to be fixed when the riser ducts are not quite ready. As a result, busducts can get damaged and wet and although they would be cleaned and dried up and meet the insulation tests, the insulation may have already been deteriorated.

### Cables

A lot of locally assembled light fittings are still internally wired with ordinary PVC cables. This has often caused melting of the PVC insulation and resulted in short-circuiting. In most cases, the faults would be cleared by the circuit protection fuses or breakers but in some instances, would cause fire.

The use of aluminium cables (as main distribution cables or rising mains) is another probable problem. The substandard part is not the cables themselves but the lack of proper treatment at connections and tee-off's where they have direct contact with copper conductors.

### Conduits

Conduits and fittings not adequately galvanised or sections with galvanising damaged such as threads at joints and bends but not properly treated could get rusted inside concrete. This may cause cracks in structures.

## 4.3 Low Standard Of Workmanship

This does not require much discussion or examples for demonstration.

With the recent requirement of registration of electrical workers and legal obligations undertaken by the workers, this cause presumably and hopefully will be gradually diminished.

To be fair however, it is not always that the electricians try to cut corners but is rather the little time and space allowed to do a proper job.

## 4.4 Inadequate Maintenance

There are many electrical installations that have never been maintained since completion.

Even some well established building management companies are not aware of the need of routine inspection, testing and servicing of an electrical installation. They often mix up repairs with maintenance, let alone those small residential buildings managed by the residents' committee comprised of layman employing retired door-keepers who would also act as the electrical experts for operating the electrical system.

## 4.5 Uncontrolled Changes And Lack Of Correct Records

If one now compares the main switchboards and the distribution systems of ten buildings selected at random with the record drawings kept by the management offices, it is very probable that over 50% of them do not match. One has to be lucky to find all ten keep record drawings. And it would be beyond one's imagination, to find the building management staff to have any idea of the original design allowance and the current usage of the electricity supply to the building.

Changes to electrical installations of buildings are rarely properly controlled. Other than a few big building management companies who would control and monitor the electrical installations of new and existing tenants, most others would simply give a complete free hand to the customers. A lot of building owners would lease or sell premises to tenants without any consideration with regard to the adequacy of electricity supply in the building to entertain new tenants' requirements.

These two factors have jointly contributed greatly to the number of sick buildings in Hong Kong.

One typical example for this is the upgrade of the capacity of a circuit without knowing the original design parameter. Very often, a circuit breaker or a fuseswitch is of a higher rating than the setting or fuse rating to suit the original design capacity. When changes are required later to suit new requirements, the circuit breaker setting or the fuse would be simply upgraded without upgrading the feeder which could therefore be overloaded.

## 4.6 Improper Spatial Planning

Needless to say, land is expensive in Hong Kong. Most space in a building would be devoted to generate revenue and as a result, it is always a difficult battle for electrical engineers to win every single centimetre for electrical use during the course of the design of a building. The hard part is however not the area but the right location and configuration.

It is not uncommon to find a main switch room blocked on one or more sides by the staircase, the lift shaft and the water tank. The installation of outgoing cables from such a switchroom would be a nightmare.

In addition, electrical riser ducts are always squeezed to the minimum not only making the initial installation of the electrical work difficult but also future inspection and maintenance cumbersome and risky.

The improper siting of the electrical riser ducts is also a potential source of the sickness. Some typical problems associated with the location of the riser ducts are:

- right adjacent to water pipes riser and as the partition between the risers is not treated with waterproofing material, any water leaking in the water pipes could leak into the electrical riser
- near or with doors facing the windows (of the staircase or light well) so that heavy rain can get flooded into the electrical switchgear
- adjacent to or underneath toilets and/or water tanks.

## 4.7 Outdated Standards, Codes And Regulations

While old codes and regulations are not necessarily unsafe, it is true that new codes and regulations are usually introduced to improve the safety considerations, to supplement any areas not adequately covered previously, to clarify ambiguity or uncertainty existed in old regulations, to agree with the latest trade practice, life style and other related regulations, etc. Electrical systems that are too old could therefore be relatively unsafe just because of the way that they were installed in addition to the more common reason of the deterioration of the wiring and components because of age.

Practices that were considered acceptable in the past but not so now include the use of rewirable fuses, the use of a main fuseswitch as also and the only earth fault protection of the whole electrical system, the running of exposed cables in protected lobbies and escape staircases, .. just to name a few.

## 4.8 Improper Planning Of Distribution Circuits

To the electronic equipment users, interference in the supply circuits and unsteady electrical supplies together have detrimental effect to their equipment.

To alleviate this problem, supply circuits to major electronic equipment (for multi-tenant office buildings, these would usually be the rising mains) should therefore be sourced from the main switchboard and preferably should be from a transformer supply separate from major motor loads such as air conditioning plants, lifts and pumps etc.

The extensive use of AC current inverters in mechanical plants also produces a lot of electrical "noise" in the electrical system and hence is a source of "uncleanliness" to electronic equipment. There are however no effective means of avoiding these within the design of the electrical system.

## 5. TREATMENT

The sickness has to be cured. The treatment is simple. Deficient electrical supply systems just need to be upgraded, substandard components replaced and problem circuits completely rewired. The actual implementation however is not as straight forward.

### 5.1 Supply Capacity Upgrade

When the main supply to a building is proved to be inadequate, the power company will need to bring in an additional low voltage (LV) supply feeder, establish a new transformer room or extend the existing transformer room depending on the extra load required and the existing supply arrangement. However, to find space within an existing building for the additional supply main is always difficult and in many cases impossible.

Some buildings can be so small and congested that even the space of installing the supply cable end box is not available. In some cases, the building may have the existing supply end box and distribution panel installed within the staircase landing, which was acceptable previously but the addition of another cable to the same space would be unacceptable under the new regulations.

The problem has to be overcome with the co-operation of the power company, the management office, the landlord and the residents committee. Some cases could be resolved by the following arrangements:

The new transformer room could be established on 1/F instead of the usual requirement of G/F. This would be dependent on the availability of such a space which has proper access and meets with FSD and BOO approval. The new transformer could even be on the roof if conditions allow.

The building management committee has to give up some carpark space or shop space and if necessary, has to purchase such a space from existing owners.

Extend a new LV supply feeder cable from power company's substation or transformer room of a nearby building. This is possible for buildings which are of the very old and small nature and most important of all, only with the existence of such a transformer room with the required spare capacity.

Supply the communal items such as lifts, pumps, staircase lighting etc. separately with an extra LV supply feeder cable. This applies to buildings with multi-tenants who do not unanimously agree to contribute fund or space to accommodate power company's new equipment.

The largest tenant or shop owner is persuaded to give up some space for accommodating the power company's new equipment.

The use of 2000 KVA transformer with a 500 KVA tertiary winding to provide extra power to the building within the existing transformer room.

As a last resort, a space may need to be sought from the Government

### 5.2 Replacement Of Switchboards

Some switchboards could be in a condition so bad that replacement of components or sections would still not be possible to alleviate the problem. This is particularly so for old switchboards without compartments difficult to be serviced and maintained. In this case, a complete replacement of the switchboard would be necessary.

The difficulty in doing so is the long period of interruption of power supply to the complete building.

Very often, a temporary switchboard located in a temporary space has to be built in order that the existing switchboard can be dismantled and the switchroom can be vacated for the installation of the new switchboard. This however would be much more costly.

### 5.3 Replacement Or Addition Of Risers

The replacement of risers can have a more difficult space problem than the replacement of the switchboard. In most buildings, the riser ducts are very tight and the risers to be replaced are not always readily accessible for removal and partition walls may need to be taken down for access. Again, a temporary riser may need to be installed so that the riser to be replaced can be de-energised.

Coring openings through slabs inside the riser ducts are always risky. Dust and dirt may get into switchgears and distribution boards which are normally not dust-tight as they are for indoor use. Slabs inside the riser ducts are usually very congested with concealed conduits which could very likely be damaged when new openings are formed.

## 6. PREVENTION

The best method of cure is to prevent from getting sick. Electrical problems should therefore be avoided before they occur. Some measures that should be taken include:

### 6.1 Proper Spatial Planning

This had been difficult in the past as there were no properly documented working clearance and access requirements. Thanks to the recently published Codes of Practice for the Electricity (Wiring) Regulations which have specifically defined such criteria.

### 6.2 Adequate Preventive Maintenance

Electrical installations should be thoroughly inspected and serviced at regular intervals. Potential problem areas should be rectified before problems occur. Again, the Codes of Practice for the Electricity (Wiring) Regulations have called for inspections and certification of installation at regular intervals. This should enable early detection of sickness.

### 6.3 Use Of Quality Equipment

The cost of an electrical installation ranges from 5% to 8% of the total construction cost of the building. The cost saving in the use of substandard materials and equipment is insignificantly little. With the extremely high land cost in Hong Kong, this saving cannot be justified.

For instance, the cost of the main switchboards for a fully air conditioned commercial complex of 100,000m2 is no more than HK$10 millions which can be fully paid back in six days (assuming a rental income of HK$500/m2).

### 6.4 Updated Records And Documents

As-built electrical drawings should be continuously updated to record all latest changes and modifications. Documents regarding the original design parameters and the current demand data should be properly kept and updated.

Sufficient data collecting and recording instruments should be installed in the distribution system to accurately and correctly monitor the load profile of the system. These instruments are in fact relatively low cost and would not increase the total cost in any noticeable order.

### 6.5 Employment Of Qualified Workers

To ensure the workmanship of the installation and the inspection and maintenance service can meet with the required safety standard, qualified workers should be employed to carry out these duties. The recent statutory requirements that only registered electrical workers can carry out the electrical works should be able to improve the standard in general.

## 7. CONCLUSION

With the current requirements of registration of electrical workers and the recent enactment of Codes of Practice for the Electricity (Wiring) Regulations, new electrical installations are expected to be relatively immune to sickness. This of course still has to rely on the joint effort of people in the industry to ensure that this goal is achieved and to continuously educate colleagues of related field and owners of buildings to be more aware of the importance of quality electrical installations.

Much more works however are necessary for existing electrically sick buildings. They need even more effort and attention. The diagnoses of these cannot be generalised and the method of treatment needs to be established depending on the individual case.