THE HONG KONG
INSTITUTION OF ENGINEERS
ELECTRICAL DIVISION

One day Symposium

Friday, 18th November, 1988

Quest for Quality and Quantity in Electrical Engineering, Hong Kong

at

Silver Ballroom
Sheraton Hotel
20 Nathan Road,
Kowloon, Hong Kong

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Symposium Programme

0.830 Registration and Coffee

0.900 Introduction

– Symposium Chairman: Mr. A. D. Longmore, BSc(Eng), DipMS, FHKIE, CEng. FIEE, MBIM

Welcomed by: Mr. S. T. Tam, BSc(Eng), MHKIE, CEng, MIEE Chairman, Electrical Division, HKIE

09.05 Opening Address

– President HKIE: Mr. N.A. Kraunsoe, BAI, MA, FHKIE, CEng, FICE, FIWES, FBIM

1. Safety & Training

09.10 Quality & Safety – A Systems Approach

– Speaker: Mr. L. T. Lee, Chief Engineer, EMSD
Mr. John H. N. Chan, Senior Engineer, EMSD

09.30 Quality and Quantity in Electrical Industry Training

– Speaker: Mr. C. K. Tsang, Chairman, Electrical Industry Training Board, VTC

09.50 Discussion Period

10.10 Coffee

2. Standard & Testing

10.40 Standards in Quality Assurance – The Way Forward

– Speaker: Mr. Brian Tyler, Head of Standards & Calibration Laboratory, Industry Department

11.00 Towards an International Standard

– Speaker: C. W. Li, Manager, Electrical & Electronic Dept. The HK Testing and Standard Centre Ltd.

11.20 Modern Electrical Test Instruments

– Speaker: Mr. Barry Clegg, Business Development Manager. BICC, H.K. Ltd.

11.40 Discussion Period

12.10 Lunch

3. New Developments

14.15 Busduct – Flexible Rising Mains System
– Speakers: Mr. Raymond Lau, Director, Electrical & Electronic Eng. Div., JEC
Mr. Lawrence Ng, Engineer, Electrical & Electronic Eng. Div., JEC

14.35 Quality Control for Nonflammable Power Transformer
– Speakers: Mr. Tatsuo Sato, Manager of Quality Assurance Centre
Mr. Atsushi Kudo, Manager of Transformer, Engineering Department B., Mitsubishi Electric Corporation

14.55 Flexible Cable Rising Mains
– Speaker: Mr. W. P. Po, Manager, Electrical Engineering Dept.,Swire Engineering Services Ltd.

15.15 Coffee

4. Installation

15.30 On Site Quality Control
– Speakers: Mr. T. L. Chau, Manager, Electrical Contracting Division, China Engineers Ltd.
Mr. S. T. Chan, General Manager, Trident Engineering Co. Ltd.

15.50 Protection against Environment
– Speaker: Dr. H. Y. Yeung, Chief Environmentalist, China Light & Power Co. Ltd.

16.10 Discussion Period

16.30 Summing up:
– Symposium Chairman
Mr. A. D. Longmore, Chief Engineer, China Light and Power Company Limited

Closing Address
– Prof. the Hon. C. K. Poon, Chairman, Committee of Science and Technology

Note: It is regretted that the Paper No.4 has been substituted due to unforeseen circumstances.

SYMPOSIUM ORGANIZING COMMITTEE

Symposium Chairman: Mr. A.D. Longmore

Organizing Chairman: Mr. A. D. Longmore

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Speakers/Authors

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Mr. C. W. Li
Mr. Barry Clegg
Mr. Raymond Lau
Mr Lawrence Ng
Mr. Tatsuo Sato
Mr. Atsushi Kudo
Mr. W. P. Po
Mr. T. L. Chau
Mr. S. T. Chan
Dr. H. Y. Yeung

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1. Safety & Training

Paper No. 1

Quality & Safety – A Systems Approach

Speakers: Mr. L. T. Lee, Chief Engineer, EMSD
Mr. John H. N. Chan, Senior Engineer, EMSD

QUALITY & SAFETY – A SYSTEMS APPROACH

Introduction

Electricity Safety is always a matter of concern for the Government. As reflected by statistics, accidents and fires that are related to electricity are not only caused by misuse or abuse of electrical appliances or equipment but also faulty electrical products or installations.

In view of this, it is considered that a systematic approach is essential and necessary, for upgrading and improving the quality of electrical work so as to ensure the safe use of electricity. The approach to be adopted by the Government is illustrated in Figure 1 with those major aspects described below:

I. Setting Safety Requirements through Legislation

It is apparent that there is a close correlation between safety and quality of electrical installations. The setting up of safety requirements for electrical installations is of vital importance.

As there are no existing common standards in Hong Kong for electrical equipment and installations, the industry now usually refer to those overseas standards or regulations from IEE, IEC or BS in their specifications. However, it is not uncommon to find that some of these overseas standards are not completely applicable to the local conditions of Hong Kong. Thus, it is considered that there is merit in establishing a set of safety requirements, based on internationally accepted standards and regulations with modifications to suit local situations. In order to ensure proper enforcement, these requirements can be made mandatory through proper legislative measures.

II. Legislation Enforcement

The whole process of establishing legislation will only be effective if there are provisions to administer and enforce the various proposed safety requirements.

Authority will be delegated to certain government officer to govern the safe use of electricity and for the purpose of quality checking, he shall be empowered to carry out inspections and testings on electrical products and electrical installations. In order to ensure public safety, he shall also be given the power to prohibit the sale, hire and use of sub-standard electrical products and to disconnect the supply to unsafe electrical installations.

III. Training & Guidance for Industry

Safety requirements will be more effectively maintained by those people who have been properly trained. From our experience, many personnel and workers engaged in the electrical industry have not received any proper training and they have only gained their knowledge from their daily work.

To assist the industry, it is advisable for Government to publish some technical guidelines in form of code of practice and guidance notes so that the industry can adapt to the safety requirements laid down in the legislation more easily.

At present, there are already training courses offered by the Vocational Training Council and other industrial organisations to train workers engaged in the industry. With a more safety conscious society, it is expected that greater emphasis will be placed on the training of the electrical trade so that the general standard of electrical workers can be brought in line with the statutory requirements.

It is anticipated, with introduction of the principles of safety through training and guidance, the general attitude and concerns of the industry towards electrical safety will be improved.

IV. Public Education

In line with setting safety requiements, as illustrated in the block diagram, public education is another important aspect considered by the Government in the systems approach to enable the general public and industry to have an appreciation of the spirit behind the legislation. It is essential not only to let them know the requirements but also to make them aware of their own responsibilities and the need for achieving electrical safety.

In fact, the necessity of public education is beyond doubt for although many people are well aware of the potential danger of electricity, they usually pay little attention to their electrical installations and have a careless attitude in handling electrical equipment.

As a first step, Government had already launched a series of public education programme including a technical seminar for electrical contractors and workers held in March this year and two short advertisements about RCD which are now being broadcasted on televisions and radios. It is planned in the coming years, besides seminars and TV advertisements, other means like exhibitions and publication of leaflets will be employed to further emphasize the message of safety.

V. Feedback to Government through Consultation

As the systems approach so far described will have significant impact on various parties like workers, contractors, manufacturers and consumers etc., comments and opinions will be collected, when the legislation are implemented, for the consideration of the Government to see if adequate guidance and publicity have been provided or where necessary, if any amendment to the legislation have to be made.

It is worth mentioning that Government has already carried out extensive discussions and consultation with various parties concerned during the drafting of the legislation. This will ensure that the legislation to be introduced to the public will be effective as well as acceptable.

Safety Requirements

As mentioned in the beginning of this paper, setting safety requirements is an important aspect of the systems approach. To illustrate the scope of those safety requirements, a number of sample requirements that are related to quality of electrical products and installations are chosen below. In connection with this, technical guidelines or testing methods on how those requirements can be met by the industry will also be given:

I. Safety Requirements for Electrical Products (Examples)

(a) Choice of Material

Insulating materials that are chosen to be used in an electrical appliance shall be tropicalised, moisture resistant, sufficiently resistant to heat, and of a class suitable for the maximum temperature rise in the normal use of the electrical appliance. The temperature rise of the insulating materials shall not be allowed to exceed certain maximum permissible limits (Annex 1). To ensure correct choice of insulating materials, various tests can be carried out and these include moisture resistance test, heat resistance test and insulation resistance test etc. A brief description of each tests is given in Annex 2.

(b) Design

(i) Main Input Terminals

Main input terminals in an electrical appliance shall be of brass material or equal, having a dimension which corresponds to the current rating of the electrical appliance. A guideline for designing the dimensions of the terminals is given in Annex 3.

(ii) Creepage Distances and Clearances

Various parts of an electrical appliance shall have sufficient electrical safety clearances so as to prevent electrical flash over, leakage or short-circuit. Minimum creepage distances and clearances for different parts of an electrical appliance are given in Annex 4.

(iii) Mechanical Strength

Every part of the enclosure housing the live parts of an electrical appliance shall be rigid and shall not deform under normal use to prevent danger arising from reducing the electrical safety clearance. Methods from testing the mehcanical strength of an electrical appliance will be provided. (Annex 5)

(iv) Stability

Electrical appliances, other than fixed appliances and hand-held appliances, intended to be used on a surface such as floor or a table, shall be designed with adequate stability to prevent the appliances from overturning which may cause hazard. Annex 6 describes tests for assessing the stability.

(c) Construction

Electrical appliances shall be constructed so that, in normal use, there will be no electrical or mechanical failure. Tests to ensure the endurance of the appliances are given in Annex 7.

II. Safety Requirements for Electrical Installations (Examples)

(a) Conductors, Joints and Connection

Every electrical joint, connection and conductor shall be properly constructed and installed as regards conductance, insulation, mechanical strength and protection. Some guidelines for cable installations and jointing are illustrated in Annex 8 and 9.

(b) Enclosures of Wiring Installations

Good workmanship and suitable materials shall be used for the enclosures of a wiring installation. Enclosures of a wiring installation includes conduits, trunkings and ducts etc. which afford mechanical protection for wires, cables and busbars. Examples of general guidelines for installation of conduits are given in Annex 10.

Conclusion

To fulfil the purpose of ensuring safety, quality in electrical work is important, but legislation can only serve as a directive to the industry.

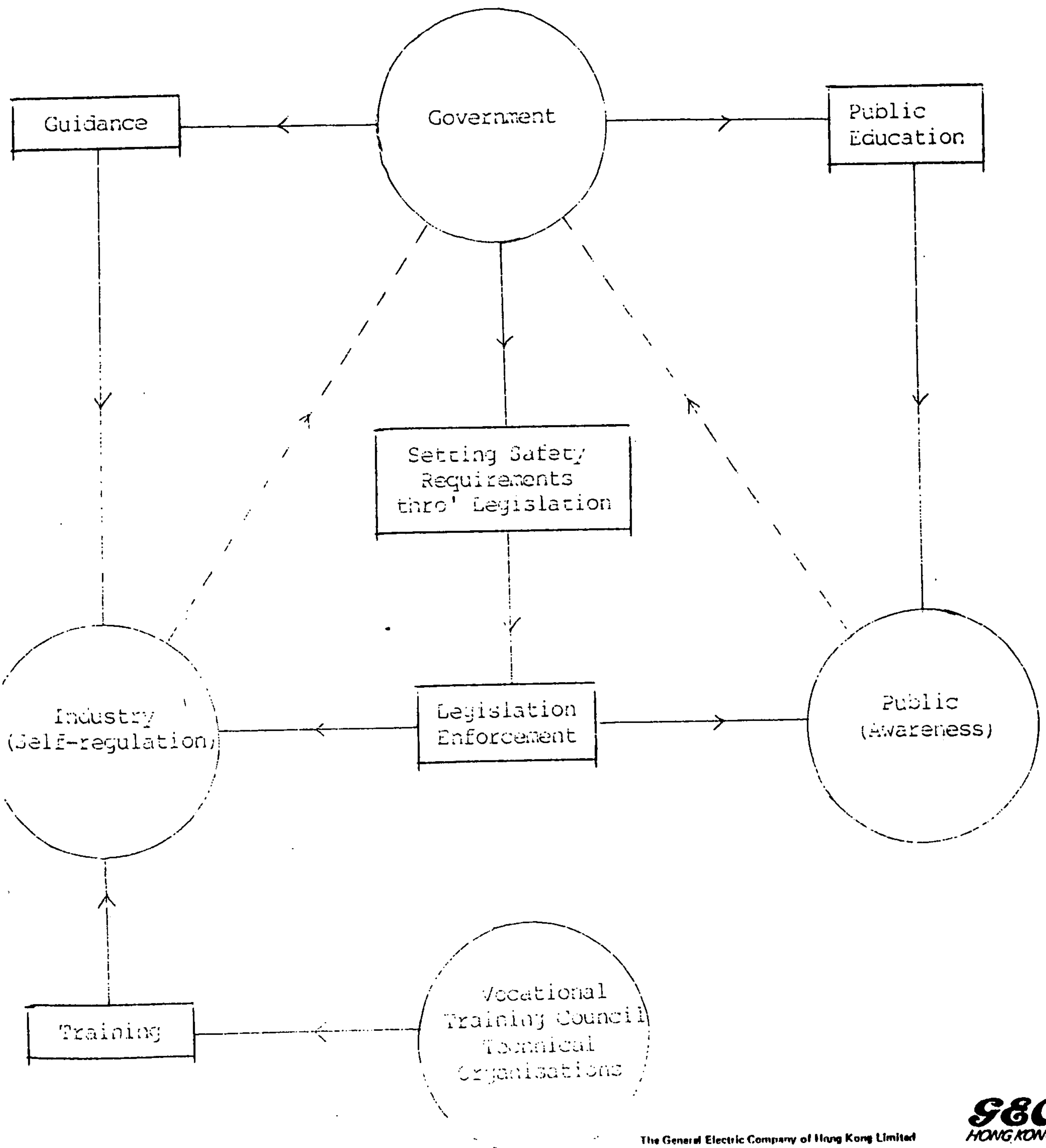
Besides enforcement of legislation of Government, self-regulation of the industry is also considered to be essential if actual compliance with the safety requirements is to be achieved. Manufacturers and importers should ensure that their electrical products conformed to the requirements, probably through recognised testing organisations. Electrical workers and contractors should observe relevant regulations or code of practice and carry out their installation works in good workmanship.

Through public education, it is hoped that the general public will take an initiative role in ensuring their installations to be safe and treat electricity with an attitude of care.

As a conclusion, under the systems approach outlined in this paper, the pursuit of quality and safety should be a goal attained by the joint effort of all parties concerned.

Figure 1

Systems Approach Block Diagram



Maximum Permissible Temperature Rise for Some Typical Insulating Materials

Part	Temperature Rise (^{o}C)
1. Rubber or polyvinyl chloride insulation of internal and external wiring including power supply cords that are without temperature rating	40
2. Rubber, other than synthetic, used as supplementary insulation or as reinforced insulation	30
3. Impregnated or varnished textile, paper or press board used as insulation other than that specified for wires and windings	60
4. Windings with insulations of:	
Class E material	80) measured by
Class B material	85) resistance
Class F material	105) method
5. Wood (in general)	55

(Note: Values in table are based on an ambient temperature normally not exceeding 35^{o}C.)

Various Tests for Electrical Insulation

1. Moisture Resistance Test

Immediately after the electrical appliances being appropriately treated (e.g. drip-proof appliances are subject to 5 minute vertical rain test), the appliance shall be able to withstand an electric strength test and there shall be no trace of water on insulation for the specified creepage distances.

2. Heat Resistance Test

A steel ball of 5 mm diameter is pressed against the test surface of insulating material with a force of 20 N. The test is carried out in a heating cabinet at a temperature of 75 ± 2°C or at a temperature which is 40 ± 2°C in excess of the permissible temperature rise specified for the material whichever is the higher. After one hour, the ball is removed and the measured diameter of the impression caused by the ball shall not exceed 2 mm.

3. Insulation Resistance Test

After applying a d.c. voltage of approximately 500V for one minute, the insulation resistance is measured and it shall not be less than that shown in table below:

Insulation to be Tested	Insulation Resistance (Mohm)
Between live parts and the body:	
- for basic insulation	2
- for reinforced insulation	7
Between live parts and metal parts of Class II appliances which are separated from live parts by basic insulation only	2

Tables of Dimensions of Main Earth Terminals and Mains Terminals

Table I – Dimensions of pillar type terminals

Rated Current of Appliance A	Minimum Nominal Thread Diameter mm	Minimum Diameter of Hole for Conductor mm	Minimum Length of Thread in Pillar mm
Up to and including 10	3.0	3.0	2.0
Over 10 up to and including 16	3.5	3.5	2.5

Table II – Dimensions of screw type terminals

Rated Current of Appliance A	Nominal Thread Diameter mm	Length of Thread on Screw mm	Length of Thread in Screw Hole or Nut mm
Up to and including 10	3.5	4.0	1.5
Over 10 up to and including 16	4.0	5.5	2.5

Minimum Creepage Distances and Clearances

Distances (mm)	Working Voltage up to 130V		Working Voltage 130V - 250 V		Working Voltage 250V - 440V	
	Creepage Distance	Clearance	Creepage Distance	Clearance	Creepage Distance	Clearance
1. Between live parts of different polarity:						
(a) if protected against deposition of dirt	1.0	1.0	2.0	2.0	2.0	2.0
(b) if not protected against deposition of dirt	2.0	1.5	3.0	2.5	4.0	3.0
(c) if lacquered or enamelling windings	1.5	1.5	2.0	2.0	3.0	3.0
2. Between live parts and other metal parts over basic insulation						
(a) if protected against deposition of dirt	1.5	1.5	2.0	2.0	3.0	3.0
(b) if the live parts are lacquered or enamelled windings	1.5	1.5	2.0	2.0	-	-
3. Between metal parts separated by supplementary insulation	4.0	4.0	4.0	4.0	-	-

Mechanical Stregth Test

The mechanical strength of electrical appliances is checked by applying blows to the sample by means of a spring-operated impact – test apparatus. The hammer head has a hemispherical face of polyamide having a rockwell hardness of R100 and with a radius of 10 mm. The hammer spring is adjusted so that the product of the compression, in mm, and the force exerted, in newtons, equals 1,000, the compression being approximately 20 mm. With the sample rigidly supported, blows are applied against the sample in a direction perpendicular to the surface at the point to be tested. After the test, the sample shall show no damage internally and externally.

Annex 6

Stability Test

Electrical appliance to be tested is placed at many normal position of use on a plane inclined at an angle of 10° to the horizontal. For appliances provided with an appliance inlet being fitted with an appropriate connector and flexible cable or cord; the cable or cord should rest on the inclined plane in the most unfavourable position. For appliances provided with doors, the appliance shall be tested with the doors open or closed, whichever is the most unfavourable. For appliances intended to be filled with liquid by the user in normal use, the appliance shall be tested empty or filled with the most unfavourable quantity of water up to the rated capacity.

Under the above tests conditions, the appliance shall not overturn.

Annex 7

Endurance Tests

1. The electrical appliance under tests is operated under normal load and at a voltage equal to 1.1 times rated voltage for a time equal to that shown in table below. The appliances shall then be operated under normal load and at a voltage equal to 0.9 times rated voltage for the time shown in the table below:

Type of Appliance	Operating Time (hr.)
Appliances having a prospective total operating time less than 15 hr. a year	15
Other appliances	48

2. After the tests are carried out, the appliances shall withstand the insulation resistance and electric strength tests specified in the Guidance Notes.

Example of Guidelines on Installation of Cables

1. All cables should be run in a vertical or horizontal direction, where practicable and should be secured flat on the surface of walls, columns, partitions or ceilings, etc, throughout the entire route.

2. Cable saddles and cable cleats should be secured by fixing screws and should be provided along the entire cable route at regular intervals. The spacing between adjacent saddles or cleats for non-armoured PVC sheathed cables should not exceed the values shown below:

Overall Diameter of Cable, D	Maximum Spacing	
	Horizontal Run	Vertical Run
Exceeding 15 mm but not exceeding 20 mm	350 mm	450 mm
Exceeding 20 mm but not exceeding 40 mm	400 mm	550 mm

3. The bending radii of PVC insulated stranded copper cables should not be less than the values given below:

Overall Diameter of Cable, D	Minimum Bending Radius	
	Non-armoured	Armoured
Not exceeding 10 mm	3D	6D
Exceeding 10 mm but not exceeding 25 mm	4D	6D
Exceeding 25 mm	6D	6D

Examples of Guidelines on Cable Jointing and Termination

1. In a straight-through joint for copper conductors, the two conductors should be butted together after the strands have been soldered solid and should be jointed by means of a weak-back ferrule, soldered to the cores. Soldering should be carried out by pouring tinman's solder over the cores and weak-back ferrule. In no circumstances should direct flame from a blow lamp be used for soldering.

2. PVC-insulated armoured cables with copper or aluminium conductors should be terminated in a gland fitted with an armour clamp. A watertight seat should be arranged to be made between the gland and inner PVC sheath. A PVC shroud should be fitted to cover the body of the gland and the exposed armour wires.

3. A compression joint should be made by inserting the conductor cores to be jointed into the opposite ends of a suitable type of compression jointing tube, which should have the correct size for the conductors. The tube should then be compressed onto the cores by means of a compressing tool. The tool used and the working procedure adopted should be as recommended by the compression joint or cable manufacturer.

Annex 10

Examples of Guidelines on Installation of Conduits

1. Galvanized saddles, for the support of surface conduits, should be provided throughout the entire route at regular intervals. The spacing between adjacent saddles should not be more than those given in the table below:

Conduit Size (mm)	Maximum Distance Between Supports (m)			
	Rigid Steel		Rigid Plastic/PVC	
	Horizontal	Vertical	Horizontal	Vertical
16	0.75	1.0	0.75	1.0
16 - 25	1.75	2.0	1.5	1.75
24 - 40	2.0	2.25	1.75	2.0
40	2.25	2.5	2.0	2.0

2. When steel conduits form part of the circuit protective conductor, the earthing terminal of the socket outlet should be connected by a separate protective conductor, having the same cross-sectional area and type as the live conductors, to a proper earthing terminal incorporated in the associated metal box or enclosure.

3. Adaptable boxes should be provided immediately after every 2 bends, or after a bend plus a total maximum straight run of 10 metres or after a maximum straight run of 15 metres.

Paper No. 2

Quality and Quantity in Electrical Industry Training

Speaker: Mr. C. K. Tsang, Chairman,
Electrical Industry Training Board,
VTC

QUALITY AND QUANTITY IN ELECTRICAL INDUSTRY TRAINING

A. The Electrical Training Board

The Electrical Industry Training Board is one of the 19 training boards established by The Vocational Training Council. This Board is to formulate policies and oversee training of relevant personnel in the electrical industry and also conduct biennial manpower survey to ascertain training needs for the future years and to recommend to the Government for appropriate action.

Briefly the scope of Electrical Industry Training Board would encompass training requirements in the following branches of the industry:

I. Manufacturing Branch

Manufacturers of electrical and associated products:

i. electrical industrial machinery and apparatus (ISIC 3831),

ii. electrical appliance and houseware (ISIC 3833),

iii. dry batteries (ISIC 3836),

iv. torch bulbs (ISIC 3837), and

v. electrical apparatus and supplies not elsewhere classified (ISIC 3839).

II. Contracting Branch

Contractors dealing with electrical equipment and systems:

i. electrical wiring and fitting (ISIC 5611),

ii. lift and escalator installation (ISIC 5612),

iii. air-conditioning and ventilation systems installation (ISIC 5613),

iv. fire alarm and fighting equipment installation (ISIC 5614),

v. cold storage (ISIC 7195), and

vi. electrical repairs (ISIC 9512).

III. Servicing Branch

Establishments providing electrical and related services:

i. public utility companies of electrical industry,

ii. relevant government departments and educational institutions,

iii. electrical and mechanical consulting engineering companies, and

iv. major trading companies of electrical products, equipment and systems and their associated servicing workshops.

The training board has representation from Universities, Polytechnics, technical institutes, utility companies, the manufacturing association representatives as well as those from the contracting branches.

B. The Background of the Present Board and the Previous Body

Industrial Training Advisory Committee

The rapid expansion of Hong Kong's industrial base and the shortage of trained manpower had prompted the Government to set up in 1965 the Industrial Training Advisory Committee (ITAC) to study the problems of industrial training and make recommendations to solve the problems.

It was ITAC's view that industry should be responsible for providing practical on-the-job training and the Government, complementary technical education. Government accepted this as a policy and began to build more technical institutes and expand the then Technical Colleges (now the Hong Kong Polytechnic) to provide more institutional training.

Hong Kong Training Council

Following ITAC's recommendations, the Government established in 1973 the Hong Kong Training Council (HKTC) as an advisory body in industrial training to replace ITAC. The scope of work of HKTC had expanded from that of its predecessor, and encompassed the study of manpower training needs at all skill levels and the formulation of plans to meet those needs. The Electrical Industry Training Board set up under the HKTC conducted manpower surveys biennially and published training materials, such as job specifications and training programmes, for training skilled workers in the electrical industry.

Apprenticeship Ordinance

Even though technical institutions were available to provide complementary theoretical education, some employers were still reluctant to release their apprentices to receive technical education in these institutions.

In 1976, on HKTC's recommendation, Government enacted the Apprenticeship Ordinance. The Ordinance stipulates that an employer employing a young person in a designated trade such as electrician, air-conditioning mechanic etc., must employ the young person as an apprentice and train him in accordance with the provisions in the Ordinance. This provides the apprentice an opportunity to learn a trade through on-the-job experience plus attendance at a relevant part-time day-release course in a technical institution. Also their practical training is closely monitored by Inspectors of Apprentices.

Recognising the need for manpower training, coupled with the legal framework made available by the Apprenticeship Ordinance, the electrical industry began to adopt formalised apprenticeship schemes to train both craftsmen and technicians. The Ordinance was the cornerstone for organised apprentice training in Hong Kong and has been instrumental in bringing about an upsurge in the number of apprentices in properly organised schemes in the decade that followed.

As demand for skilled technicians and craftsmen continued to grow and very few contractors/employers could provide well-organised off-the-job basic skill training to their recruits, the Electrical Industry Training Board proposed an industrial training scheme for the electrical industry. Under this scheme, trainees could obtain full-time basic skill training for a trade.

Vocational Training Council

In 1982, Government set up the Vocational Training Council (VTC), a statutory organisation with both advisory and executive functions, to replace the HKTC. Under the VTC set-up, training efforts can be better coordinated with technical institutes and training centres being covered under the same administration.

The Electrical Industry Training Board was set up under VTC to implement, inter alia the proposed training scheme for the electrical industry.

Electrical Industry Training Centre

The Electrical Industry Training Centre, developed and operated by the Electrical Industry Training Board, started operation in September 1985. The Training Centre occupies about 3,300 m^2 at the Kwai Chung Training Centre Complex at San Kwai Street, The Training Centre offers one-year full-time basic craft courses in electrician/electrical fitter, refrigeration/air-conditioning mechanic, and lift mechanic/lift electrican. On completion of training, the trainees are expected to join the electrical industry as second year apprentices for a further 3 years on-the-job training. The Centre also offers three upgrading evening courses for electricians, lift mechanics/lift electricians and air-conditioning mechanics.

C. Quantity of Training

The training of the various levels of craftsmen and technicians rely heavily on to the various technical institutes. Based on the biennial manpower survey and the forecast so obtained, the Government has been spending a lot of money in the provision of technical education. For the technical institutes, they have been established throughout the last 20 years from a mere one to eight TIs being now in full operation. These eight technical institutes which offer courses at craftsmen and technicians courses are as follows:

Technical Institutes	Start-Up Year
Morrison Hill	1969/72
Kwai Chung	1975/76
Kwun Tong	1975/76
Haking Wong	1977/78
Lee Wai Lee	1979/80
Tuen Mun	1986/87
Shatin	1986/87
Chai Wan	1987/88

Although not the entire curriculum in these technical institutes are devoted to the electrical industry, yet every one of them would have a number of courses devoted to such.

Due to the forecast in demand in technologist level in the electrical industry coupled of course with demand in other industries, the Government has already established the City Polytechnic as well as the decision to go ahead with the University of Science and Technology which is affording enough trained personnel to foster the electrical industry. Of course much of the planning work for the University and Polytechnic come under the University and Polytechnic Grants Committee, but much reference is made to the manpower demand as a result of the biennial manpower survey undertaken by the Electrical Industry Training Board.

The following are tables of the growth in numbers and vacancies in the electrical industry for all the three levels. (Appendix I)

D. The Engineering Graduates Training Scheme

The Hong Kong Institution of Engineers has introduced the Engineering Graduates Training Scheme to formalise recognition of training opportunities in the various industrial establishments in Hong Kong. However, since the Hong Kong Institute of Engineers is a learned society, much of the groundwork of liaising with industrial establishments etc. are done through the Vocational Training Council. Moreover, especially in the electrical industry, many industrial establishments may not have the full facilities required for graduates' training and hence the electrical industry training centre has been assisting this EGTS since its establishment in 1985.

The following is a table showing the numberof firms and the number of training schemes established for the engineering graduates which has shown a steady increase in this area affording better training opportunities leading to become technologist level.

Date	No. of Firms	No. of Training Schemes
As at 31.3.84	6	14
As at 31.3.85	11	22
As at 31.3.86	15	31
As at 31.3.87	30	54
As at 31.3.88	32	59

It is with a foresight of the Hong Kong Government and the understanding of the lack of resources of Hong Kong that good, skilled and trained personnel would be the backbone of the industry in Hong Kong. In the last few years, the export-led industrial growth has led to an unprecedented prosperity in Hong Kong and it can be said that this cannot be possible without a skilled pool of resources available. Nevertheless the demand for skilled craftsmen, technicians and technologist are still growing and we cannot be complacement with the present achievement and have to look even further ahead to maintain the importance of Hong Kong as an industrial centre.

Year	No. of Employees			No. of Trainees			No. of Vacancies at Date of Survey			Forecasted No. of Employees by March Next Year		
	Technologist	Technician	Craftsman	Technologist	Technician	Craftsman	Technologist	Technician	Craftsman	Technologist	Technician	Craftsman
1975	1,081	2,156	13,808	17	148	3,255	38	38	123	1,161	2,274	14,262
1977	1,294	2,057	17,152	58	131	2,474	28	55	800	1,381	2,243	18,939
1979	1,528	2,349	18,427	89	292	3,093	134	197	1,493	1,750	2,832	21,065
1981	2,164	3,951	24,025	141	416	3,338	348	338	1,436	2,612	4,561	26,808
1983	2,655	4,539	27,214	361	559	3,401	131	245	611	2,824	4,958	26,391
1985	3,103	5,240	28,459	281	366	3,165	227	298	1,115	3,459	5,843	30,313
1987	3,223	6,186	25,275	182	328	2,135	116	359	1,119	3,433	6,702	26,819

2. Standard & Testing

Paper No. 3

Standards in Quality Assurance – The Way Forward

Speaker: Mr. Brian Tyler, Head of Standards & Calibration Laboratory, Industry Department

'STANDARDS IN QUALITY ASSURANCE – THE WAY FORWARD'

In preparing this talk I was very mindful of the plethora of information written and published, particularly in recent years, on the subject of standards and quality assurance. Worldwide there is currently so much interest in all aspects of these subjects.

Here in Hong Kong we have held several conferences on the subject of quality and many opportunities are used to promote the perceived benefits of introducing quality assurance methods into many industrial and business activities. So perhaps we should consider why there is such interest in quality and what, if any, significance this has for Hong Kong in 1988 and thereafter.

Hong Kong's manufacturing industries and economic success

The economic success of Hong Kong for the past several decades has relied very heavily on the success of its manufacturing industries and this is likely to remain the situation for many years to come. From this success has developed a higher standard of living for all the people in Hong Kong leading in general to a better quality of life. It would therefore be sensible to try and analyse the reasons for the success and to attempt to sustain the situation.

Well clearly we have been able to supply goods that are in demand in the world at a price and with a delivery time which has been very competitive and has resulted in economic success. But this very success which has led to an improvement in the standard of living here has inevitably meant that the cost of production in Hong Kong has risen. Additionally our overseas markets are seen to be coming more discerning regarding the quality of the products that they wish to buy. In some cases relating to safety aspects, overseas Government regulations, now frequently mandatory, are necessitating revisions to the design and materials of production of products before they can be sold to such markets.

All these factors lead towards increased production costs and constitute a considerable challenge to our entrepreneurs, to our labour force and to the Government in attempting to maintain a successful and buoyant economy, underpinned by a viable and progressive manufacturing industry. Even today, a large proportion of our exports are relatively labour intensive or fall into the category of 'original equipment manufacture' (OEM) which consists largely of sub-contracting work with a relatively low technology level and hence low value added content. But at the same time we are finding that our competitive edge in terms of price is being eroded and other countries particularly in southeast Asia can produce similar goods, but at a lower price. In certain cases manufacturers are subcontracting some of the work to such countries (e.g. it is estimated that between 1 and 2 million workers are now employed in manufacturing by or on behalf of Hong Kong firms in Guangdong province alone) or alternatively relocating their manufacturing operations elsewhere.

It is clear that Hong Kong cannot continue for too long in this situation despite the fact that it has brought success in the past. We are becoming too expensive for this type of manufacturing operation. In fact, even in the case of goods of higher value added, especially in the field of consumer electronics, the continuing growth in our exports has masked the fact that we are losing market share to some of our Asian competitors (for example according to US Department of Commerce statistics, Hong Kong's share of US imports of electronics by value decreased from 6.4% in 1983 to 3.7% in 1986).

So here we have the picture, a forecast if you like, of Hong Kong being unable to compete with the low cost production of its 'traditional' products in neighbouring countries and finding that its more 'sophisticated' products are being severely scrutinised, in terms of quality and health and safety standards by increasingly affluent overseas markets. Having 'set the scene' I would now like to return to the question of standards in quality assurance, if not 'the way forward' at least a suggested route for possible future developments in our manufacturing industries.

The worldwide 'quality movement'

Most discussions concerning the quality of products usually start with a definition similar to:

> "The quality of a product is the degree of conformance of all the relevant features and characteristics of the product to all of the aspects of a customer's need (limited only the price and delivery he or she will accept)" – 'The Chain of Quality' – John M. Groocock.

This definition emphasises the important point that a product does not inherently have quality – it has a quality only in relationship to a customer's need (although in some cases the need for quality might go beyond the customer's immediate perception, in such things as compliance with mandatory regulations or in the safety requirements of third parties).

What is apparent in studying the trends in our major overseas markets, is that customers are becoming more quality conscious and goods supplied have to be better value for money in terms of their design performance, safety and durability. We are seeing developments in Europe in respect of harmonisation of standards and in that market and in the USA the introduction of mandatory safety requirements in respect of certain classes of consumer and other products (the EEC Toy Directive which comes into force on 1 January 1990 is a typical example). This legislation will have a considerable impact on the available market access of products which do not comply with these new requirements and regulations.

'Quality' in manufacturing in Hong Kong

Some very basic but important facts relating to Hong Kong's economically successful manufacturing industries are given in Appendix 1. All recent studies which have been undertaken in respect of the major industries listed, have indicated that in order to maintain our success Hong Kong must 'move up market' in the quality of its manufactured goods and 'improve its image' as a possible source of quality products. That is not to say that we do not have manufacturing companies here producing goods of excellent quality (some manufacturers are employing the very latest techniques to produce goods for the sophisticated requirements of very discerning overseas customers), but taking industry as a whole, there is room for a vast improvement in the way that manufacturers conduct their operations.

We have been warned that there must be a very much greater appreciation of quality in manufacturing – a quality awareness needs to be generated and the ways and means to produce the desirable, in fact the very necessary, quality products, must be made known to all involved in manufacturing.

The major share of responsibility for embracing this 'quality message' (and taking action in response to it) must be the chairman and managing directors of our manufacturing companies. They will need to be convinced that moving along the 'quality road' or perhaps more graphically climbing the 'quality ladder' is the only route to continuing success in their operations. However, in this venture they will need the full support of their senior and middle managers, who should possess the expertise for carrying through the quality related activities and their workforce who will need the enthusiasm and skills for the vital 'shop floor' operations that will underpin the company's complete quality strategy.

The 'quality message', at perhaps its most blatant, for both management and general workforce in our industries is that their future employment and remunerative expectations depend upon the continued success of Hong Kong industry in general and their own company enterprise in particular, which can only be sustained if quality methods are introduced into their company's operations.

Now everything I have said regarding the need for Hong Kong's industries to embrace the 'quality message' has been stated in very general terms. Perhaps I should now try to be more specific and consider how this 'message' is to be translated into action to achieve the required results and ensure that products manufactured in Hong Kong achieve the necessary quality standards and that essential market share on the world 'trading floor' (as John Groocock phrases it "... market dominance through product superiority".....).

Quality Assurance

This term can be defined as

"all activities and functions concerned with the attainment of quality".

From this simple but elegant definition we can begin to develop all the essential management techniques necessary to achieve quality in manufacturing. It involves management techniques, because when you have a group of people, perhaps individually very talented, engaging in say a manufacturing company and each performing a given task in the 'chain of production' (particularly where complex tasks are involved), it takes determined and specialist management to make it all work. But the benefits to be derived from the introduction of sound quality assurance methods into a company are substantial and hopefully even irresistable!

Now there is available considerable authoritative literature concerned with the subject of quality assurance (some useful publications are listed at Appendix 2) and there are also many (specification) standards available from various countries (see Appendix 3) which can be used as tools in applying quality assurance techniques – in essence as short cuts from other people's experience to good design and practice. In fact a number of specification standards are concerned specifically with quality assurance and related activities themselves (some of these are listed in Appendix 4).

If we examine our industries we can expect to find many companies not employing any specific quality related activities, but in others quality assurance techniques being applied with varying degrees of sophistication. At the very lowest rung of the 'quality ladder' we might find simple post production inspection techniques, at the next level a modest level of quality control combined with product inspection and test and so on until in some (perhaps a very few) companies a total commitment to quality assurance methods.

Despite what might be wide differences between our "least quality conscious" and 'most quality conscious' companies, it is vitally important to introduce them to the idea of 'quality improvement' i.e. at what ever stage a company is, in the adoption of quality assurance methods, there is always room for improvement, perhaps by incremental changes resulting in modest but nevertheless continuing improvement up the 'quality ladder' or possibly driven by market forces, by more significant 'step changes' as a result of a complete re-evaluation of a company's operations.

When all the employees of a company from managing director to receptionist or even the casual worker are fully involved in a well documented and fully practised quality management system, then the company can be said to be in the Total Quality Management state. However, this is an ultimate state more readily approached by a system of quality improvement steps introduced in a planned manner by progressive managements.

Now I have still not considered in any detail what might be the most appropriate methods for the introduction of quality assured methods into our industries (i.e. for those industries who have yet to adopt any methods or who are not sure of the next step or 'rung of the quality ladder' to take). There is considerable data available on the subject of quality and quality assurance methods and also many standards relating to the subject. It would be impossible in a short talk such as this to cover even the rudiments of the subject except in very broad outline, but I have listed in Appendices 2, 3, 4, 5 and 6 sources of authoritative information and various publications which make excellent reference material. Nevertheless I would like briefly to examine in a little more detail the international trend in this work and draw your attention to a definitive set of documents on Quality Assurance which have recently been published by ISO.

The international standards situation in respect of Quality Assurance

Over the past decade or so, a number of countries have been developing national standards for quality systems to be used in manufacturing and other activities and as a result of international discussion and agreement, a recently introduced standard or group of standards have emerged which are the quintessence of the most authoritative work undertaken in this area (particularly by British Standards Institute in the development of BS5750). This new group of standards form the ISO 9000 series.

ISO 9000 Series of standards relating to Quality Assurance

This group of standards consists of the following documents:

ISO 9000 'Quality management and quality assurance standards – Guidelines for selection and use'

ISO 9001 'Quality systems – Model for quality assurance in design development, production, installation and servicing'

ISO 9002 'Quality systems – Model for quality assurance in production and installation'

ISO 9003 'Quality systems – Model for quality assurance in final inspection and test'

ISO 9004 'Quality management and quality system elements – Guidelines'

These documents (as can be seen from their titles) offer three different levels for assessing whether or not a manufacturer's quality management system meets international levels of acceptability.

The most comprehensive assessment as described in ISO 9001, is applicable to manufacturers where quality assurance activities include design, manufacture, delivery, installation, maintenance and virtually all their operations.

The detailed assessment as described in ISO 9002, applies to manufacturers who are provided with the design and specification by their customers or in some other way.

The assessment as described in ISO 9003, can be used when the product and/or manufacturing processes are simple enough for their conformity with the specification to be determined from final inspection.

These standards make excellent reading as examples of the very latest developments in the subject and they can form the basis for a review of a company's operation and point to a development plan for improvement in the systems being used. They also provide a means to determine how closely the company's quality assurance activities are aligned with international practice.

Quality Assurance and the smaller company

As discussed earlier in this paper and as exemplified by the data contained in Appendix I, the majority of Hong Kong's manufacturing companies are relatively small. It is therefore necessary to consider how a demand for improved quality in manufacture is likely to affect their operations.

Now many of such companies act essentially as subcontractors, supplying either major overseas manufacturers direct (OEM type of operations) or larger local manufacturers, who incorporate the parts produced by the smaller factories into their products, which are then exported to fulfil an overseas customer's order. In either case a demand for better quality from either the overseas or local manufacturer will necessitate the smaller company re-examining its management methods, production processes ..... etc. to meet the improved quality demands. The alternative is to see a decline in orders and possible failure of the company.

The cost of 'quality' in manufacturing

Companies, particularly the smaller operations, are often (understandably of course!) concerned with the question of the cost of introducing quality assurance methods into their operations. Now even if one ignores the alternative scenario of possible failure of the company as a whole if they are not introduced, the interesting fact that emerges in considering this question, is that the introduction of sound quality assurance methods into a company's operations actually reduces overall costs and improves profitability. This fact was dramatically phrased but perhaps almost understated in the title of a best selling book on the subject entitled 'Quality is Free' (P.B. Crosby, McGraw Hill 1979).

For most companies large or small that have not adopted quality assurance methods in their operations, it will be found that for relatively little or perhaps no cost, a reorganisation of their management system and some relatively minor changes to their production process can frequently show immedite financial benefits and improved profitability. Such initial efforts will also pave the way for further movement up the 'quality ladder', which will again reduce overall costs and provide a better guarantee that the required degree of quality is built into the products being produced, to ensure customer satisfaction and full order books.

I should perhaps now say a few words regarding the Government's perceived involvement in standards and quality assurance activities.

The emerging 'quality in manufacturing' scene and Government

I think it would generally be agreed that Government must have a key co-ordinating role to play in all the activities I have mentioned. In fact, Government has already been very actively involved in developing a number of essential technical support services, which are a prerequisite to the further development of quality assurance practices in our industries.

These services have been primarily developed by Industry Department and include the Standards and Calibration Laboratory, the Hong Kong Laboratory Accreditation Scheme and the Product Standards Information Bureau. The services they offer are briefly described as follows:

The Standards and Calibration Laboratory

The Government Standards and Calibration Laboratory is the custodian of Hong Kong's official reference standards of measurement. These are high echelon measurement standards traceable by regular re-calibration to premier overseas institutions such as the National Physical Laboratory (NPL) UK and National Bureau of Standards (NBS) USA. The standards are maintained under a closely controlled environment and made available to industry and other users by the provision of a precision calibration service.

The laboratory has the capability to provide a very high level calibration service for customers' own reference standards and precision measuring equipment in the d.c., low frequency a.c., radio frequency, temperature, mass and length measurement fields. Under active development are facilities to provide an appropriate service for precision mechanical measurements, pressure measurements, force measurements (to ± 3MN) and humidity measurements. The laboratory also performs the role of a measurement standards reference laboratory in support of recently enacted Weights and Measures Legislation.

The laboratory has been independently assessed and accredited by NPL, UK, (through its National Measurement Accreditation Service (NAMAS)) for a wide range of electrical, temperature and mass measurements and will continue to extend the scope of this accreditation in line with the developing needs of Hong Kong. It is listed in the NAMAS Directory of Accredited Laboratories.

The laboratory participates in international metrology conferences, (e.g. the Conference on Precision Electromagnetic Measurements (CPEM)) and acts as the focus for all precision measurement activities both locally and in our contacts with overseas institutions.

The Hong Kong Laboratory Accreditation Scheme (HOKLAS)

HOKLAS also forms part of the Government's technical support services for industry. The scheme launched in 1985 has been established in accordance with international practice (e.g. ISO guide 25) and has the following objectives:

(i) to officially recognise competent laboratories

(ii) to upgrade the standard of testing and management of Hong Kong laboratories

(iii) to promote the acceptance both locally and (particularly) overseas, test data and certificates issued by HOKLAS accredited laboratories.

The scheme is managed by an Executive Administrator and a secretariat of professional staff within Industry Department. Policy and technical advice to the executive are provide by two advisory committees, namely the Advisory Committee on Laboratory Accreditation (ACLA) and the Independent Technical Assessment Board (ITAB). [A range of available literature describing the scheme and its operation is listed at Appendix 7.]

The process of accreditation involves meeting both technical and non-technical criteria and the actual assessments are conducted by technical specialists appointed on a part-time basis by ITAB. The assessors reports are also evaluated by ITAB and a recommendation regarding the granting of accreditation to the particular laboratory is prepared for consideration by the HOKLAS executive.

If a laboratory being assessed is considered to have met the necessary requirements for accreditation i.e. by complying with the HOKLAS quality criteria, then accreditation approval is granted and the HOKLAS logo can be displayed on all test certificates issued for testing which falls within the approved scope of accreditation.

The scheme was initially established to meet the needs of the manufacturing for export sector of industry and accreditation activities were organised under four product categories i.e. (i) Textiles (ii) Toys (iii) Electrical & Electronic Products and (iv) Food. However, in addition to these four major categories, a common service 'Calibration' was included in view of its importance in relation to the calibration accuracy and traceability of measurement of the equipment used in the testing laboratories.

Since its initial inception HOKLAS has broadened its accreditation scope and for example a Construction Materials group is now included within the scheme. More recent activities have involved the introduction of Environmental Testing and examination of the problem associated with Site Testing and Sampling Methods. At a later date it may be necessary to include medical and various other testing laboratories under the 'accreditation umbrella'.

The scheme will in general continue to be expanded as additional needs and assessed demands for the accreditation of other testing facilities in Hong Kong are clearly identified.

Product Standards Information Bureau (PSIB)

Since Hong Kong is (most significantly) an export oriented economy, it has generally to produce products in accordance with the (overseas) standards requirements of customers and consequently does not have a well developed system of (Hong Kong) technical regulations, standards or certification requirements for products (although there are certain measures which relate to food and drugs, dangerous goods ... etc which are embodied in our laws). As far as manufactured products are concerned, industry is interested in meeting the standards, requirements and specifications stipulated by its major overseas markets.

Now such information (including all the standards mentioned in this talk) can be obtained from the Product Standards Information Bureau, which has been established in Industry Department since 1985. It is the repository of more than 80,000 specification standards from all our major trading partners (see Appendices 3 and 4) and provides an information service to industry and any other users in Hong Kong of overseas product safety, health and certification standards and requirements. A technical advice service which aims as far as possible to interpret the technical content of overseas specifications is also available and where appropriate can offer suggestions on ways to better enable a product to meet the stipulated requirements.

Hong Kong's link with ISO is maintained through the Bureau and we have observer status at various ISO meetings, (at a later date our membership status may be reviewed to allow for a more significant contribution to international standards development).

The Bureau will continue to develop its standards library and its monitoring service in respect of developments in overseas product requirements and dissemination of the information on product standards regulations and certification requirements to local manufacturers and exporters. There are plans to strengthen the links with British Standards Institution (BSI) and make direct on-line use of their extensive standards information data bases. Contacts are also being strengthened with the appropriate authorities in USA, Europe and our other major trading partners.

Education and Training in Quality Assurance

Another topic of vital importance to the successful development of more quality awareness and quality assurance appreciation in Hong Kong is the question of sound education and training in these subjects. In this regard the Government will be, of course, fundamentally involved in the process through the tertiary education institutions such as the Universities, Polytechnics and Technical Institutes and also through the Vocational Training Council activities in specific industry sectors.

The required formal education and training in Quality Assurance may form part of a larger course (although in such cases due to time constraints it is frequently diffiicult to know what to delete from a syllabus, if new subjects are to be introduced), or may be offered as a special subject in its own right. There will also be a need to hold, from time to time, short courses on specific topics.

In addition industrial companies themselves will need to develop appropriate training methods, including periods of formal instruction. These would involve all personnel of the company including the top management. For companies requiring assistance in developing a quality management system or in the introduction of quality control methods into specific manufacturing operations, the services of the Hong Kong Productivity Council (HKPC) are available.

Complementing the above activities, the HKIE should continue to lend its full support to any quality related initiatives and to organise appropriate meetings and seminars, publish technical papers ... etc to assist in the process of inculcating the quality concept in Hong Kong.

A Quality Strategy for Hong Kong

In the light of developments in our manufacturing industries and major overseas markets, as described previously, and taking account of the more established state of the quality services infrastructure, as described above, the Government recently commissioned a consultancy to examine methods of implementing a territory wide system for promulgating 'quality' as a total concept. The consultancy remit was to advise, inter alia, on the development of a quality strategy for Hong Kong aimed at promoting maximum competitiveness for Hong Kong products and associated services, especially in international markets and also to advise on a campaign and programme for the implementation of such a strategy including recommendations for the strengthening of existing resources and the development of new services and facilities.

A consultant was engaged through Resource, UK (a Department of Trade & Industry UK/B.S.I. consultancy company) and his report (1) mapped out a quality strategy for Hong Kong. Analysis of the report and its recommendations has resulted in the establishment of a Quality Services Division within Industry Department to co-ordinate and develop the services of the Standards and Calibration Laboratory, HOKLAS and the PSIB and to act as the focus within Government for all quality related activities. In addition an adhoc committee was established – the Quality Assurance Committee (QAC) – chaired by the Director of Industry with members drawn from executives of major companies, the Trade Development Council, the Consumer Council, Productivity Council, Hong Kong Quality Circles Association, Federation of Hong Kong Industries, Chinese Manufacturers Association, and Government Departments. The committee provides advice to the Director of Industry on various quality related matters.

As a result of various discussions and deliberations of the QAC in respect of the quality strategy proposed in the Williams Report, it was considered necessary to commission additional consultancies to deal in detail with two significant aspects of the proposals, namely, the planning of a Quality Awareness Campaign for Hong Kong and the feasibility of introducing a Quality Certification (Accreditation) Scheme for companies.

The consultants, acknowledged experts in quality assurance matters, have recently submitted their reports. These will be studied, analysed and evaluated and it is anticipated that a comprehensive package of proposals relating to the need for a major Quality Drive in Hong Kong will be presented to the Industry Development Board, for consideration at its meeting in December. Subject to IDB endorsement of the package of proposals the main campaign is anticipated to be launched in 1989.

(1) Development of a Hong Kong Quality Strategy – Mr. Eric Williams. Resources Consultant. 1979

Conclusion

Well this has been a rather brief overview of a subject which could occupy many hours of discussion (if not debate!) but I hope that I have been able to show that the Government in monitoring trends in our world markets and developments in our local industries, is very aware of the need to address the whole question of international developments in standards and quality assurance methods. It has pragmatically and methodically developed a range of quality support services which will continue to be enhanced in line with Hong Kong's needs and it is new well placed to initiate a sustained Quality Drive to bring home more forcibly to Hong Kong and in particular our manufacturing industries the vital need to come to terms with and actively adopt sound quality assurance methods in their operations in order to maintain successful businesses and a sound but buoyang economy.

Some basic facts and figures concerning Hong Kong and Hong Kong manufacturing industries

1. Only about 20% of Hong Kong's total area of 1071 sq. kilometers is flat enough for development, the rest consists of hilly land which is too steep for large scale comprehensive development.

2. The territory has virtually no natural resources of its own and has to depend upon external sources for most of its daily requirements. In order to pay for such imports we have to rely on our exports.

3. Over 90% of our manufactured products are exported and these are effectively the mainstay of Hong Kong's successful economy.

4. With a population of 5.7 million Hong Kong is one of the most densely populated places in the world.

5. The total workforce is about 2.7 million and approx. 875,000 are employed in manufacturing (i.e. about one third of the total) which is the largest employer.

6. The severe shortage of developable land had led to the development of light industries which can be accommodated in multi-storied factories characteristic of the 'skyline' of Hong Kong's industrial areas. These factories are predominently small to medium sized establishments, with more than 97% of them employing less than 100 workers. (The remaining 3% of factories, i.e. the larger firms employing more than 100 workers, account for more than 50% of our industrial output!)

Size of establishment (persons employed)	No. of establishments: No.	No. of establishments: % Share
1-4	22,730	46
5-9	11,055	22.4
0-19	6,752	13.7
20-49	5,355	10.8
50-99	2,137	4.3
100-199	857	1.7
200-499	389	0.8
500-999	98	0.2
1000-1999	30	0.1
2000 and over	2	neligible
	49,403	100.0

Note that nearly 50% of the factories employ less than 10 persons, and about 97% employ less than 100. However, the small and medium operations interact closely with the bigger firms in a network of sub-contracting which can respond quickly to changes in demand.

7. The main industries (1987 figures) are:

	Employment		Domestic Exports	
	No.	%	HK$m	%
Textiles & clothing	373,000	42.6	81	41.5
Electronics	91,000	10.4	32	16.4
Plastic Products	84,000	9.6	14	7.2
Watches & Clocks	32,000	3.7	14	7.2
Electrical Products	44,000	5.0	12	6.2
Metal Products	50,000	5.7	5	2.6
Others	201,000	23.0	37	18.9
	875,000	100.0	195	100.0

Note that textiles and clothing are by far the largest contributor (i.e. approx. 41.5%) to our domestic exports and if electronic products are grouped togetherwith watches and clocks (a large proportion of which contain electronic parts) and electrical products, this group would account for a further 30% (approx) of our exports.

8. A large proportion of our manufactured products are relatively labour intensive or fall into the category of original equipment manufacture (OEM), which consists of sub-contracting work with a relatively low technology level and hence low value added content.

List of some useful books

	Title	Author	Publisher
(1)	Quality is Free	Philip B. Crosby	McGraw Hill 1979
(2)	The Chain of Quality	John M. Groocock	John Wiley & Sons Inc 1986
(3)	In Search of Excellence	Thomas J Peters Robert H. Watermann Jr.	Warner Books 1982
(4)	Quality Without Tears	Philip B. Crosby	McGraw Hill 1984
(5)	A Passion for Excellence	Thomas J. Peters	Random House 1985
(6)	Guide to Quality Control	Dr. Kaoru Ishikawa	Asian Productivity Organisation
(7)	Quality Control Handbook	J. M. Juran F. M. Gryna Jr. R. S. Bingham Jr.	McGraw Hill
(8)	Quality Planning and Analysis	J. M. Juran Frank M. Gryna Jr.	McGraw Hill 2nd Edition 1980
(9)	Total Quality Control	Armand V. Feigenbaum	McGraw Hill 3rd Edition 1983

List of Overseas Standards held by the Product Standards Information Bureau

N.B. In the majority of cases only selected standards or parts of the full set of standards are available

(A) National Standards

(1) UK

BS/BSI	:	British Standards Institution

(2) F. R. of Germany

DIN	:	Deutsches Institute fur Normung
VDE	:	Verband Deutscher Elektrotechniker

(3) U.S.A.

CFR	:	Code of Federal Regulations
ANSI	:	American National Standards Institute
(ANSI/	:	approved American National Standards on any of the following organizations are designated with 'ANSI' as prefix.)

N.B. Organizations holding less than 20 standards are not stated below.

AATCC	:	American Association of Textile Chemists and Colorists
AAMI	:	Assn. for the Advancement of Medical Instrumentation
ACI	:	American Concrete Institute
ADA	:	American Concrete Institute
ADA	:	American Dental Assn.
AFBMA	:	Anti-Friction Bearing Manufacturers Assn., Inc
AHAM	:	Assn. of Home Appliance Manufacturers
ANS	:	American Nuclear Society
API	:	American Petroleum Institute
ARI	:	Air-Conditioning and Refrigeration Institute
ASHRAE	:	American Society of Heating, Refrigerating & Air-Conditioning Engineers
ASME	:	American Society of Mechanical Engineers
ASTM	:	American Society for Testing of Materials
AWS	:	American Welding Society
AWWA	:	American Water Works Assn.
EIA	:	Electronic Industries Assn.
IEEE	:	Institute of Electrical and Electronics Engineers
IPC	:	Institute of Printed Circuits
ISA	:	Instrument Society of America
NEMA	:	National Electrical Manufacturers Assn.
NEPA	:	National Fire Protection Assn.
SAE	:	Society of Automative Engineers
SMPTE	:	Society of Motion Picture & Television Engineers
TAPPI	:	Technical Assn. of the Pulp and Paper Industry
UL	:	Underwriters Laboratories

(4) Canada
CAN : National Standard of Canada
(CAN/ : approved National Standards of Canada on any of the following organizations are designated with "CAN' as prefix, or represented by CAN1, CAN2, CAN3 OR CAN4)
CAN1/CG : Canadian Gas Association
CAN2/CGSB: Canadian Govt. Specification Board
CAN3/CSA: Canadian Standards Association
CAN4/ULC: Underwriters' Laboratories of Canada

(5) Australia
AS/SAA : Standard Association of Australia

(6) Japan
JIS : Japanese Industrial Standards

(7) South Africa
SABS : South Africa Bureau of Standards

(8) New Zealand
SANZ : Standards Association of New Zealand

(9) China (PRC)
GB/CSBS : State Bureau of Standards

(10) Sweden
SS : Swedish Standards

(11) Cuba
CDU : Norma Cubana

(12) India
IS : Indian Standards

(13) Thailand
TIS : Thailand Industrial Standards

(14) Singapore
SS : Singapore Standards

(15) Saudi Arabia
SASO : Saudi Arabian Standards Organization

(B) International Standards

ISO : International Organization for Standardization
IEC : International Electrotechnical Commission
CEE : International Commission for Conformity Certification of Electrical Equipment

List of Standards relating to Quality control, Metrology and Laboratory testing/accreditation

Quality Assurance/Quality Control

BSI

BS 2564	Control chart techniques when manufacturing to a specification, with special reference to articles machined to dimensional tolerances.
BS 4778	Quality vocabulary (consists of two parts).
BS 4891	A guide to quality assurance.
BS 5700	Guide to process control using quality control chart methods and cusum techniques.
BS 5701	Guide to number-defective charts for quality control.
BS 5703	Guide to data analysis and quality control using cusum techniques.
BS 5750	Quality systems (Consists of 4 parts together with 3 parts of guides. Some of the parts are identical with ISO 9000 series)
BS 5760	Reliability of constructed or manufactured products, systems, equipments and components.
BS 6000	Guide to the use of BS 6001, sampling procedures and tables for inspection by attributes.
BS 6001	Sampling procedures for inspection by attributes.
BS 6002	Specification for sampling procedures and charts for inspection by variables for percent defective.
BS 9000	General requirements for a system for electronic components of assessed quality. (Consists of 3 parts)
PD 9004	BS 9000, CECC & IECQ UK administrative guide.

JIS

JIS Z8101	Glossary of terms used in quality control.
JIS Z9001	General rules for sampling inspection procedures.
JIS Z9021	Control chart method.

JIS Z9022	Median control chart (No English version)
JIS Z9023	X control chart.
JIS Z9031	Random sampling methods.

ISO

ISO 2859	Sampling procedures and tables for inspection by attributes.
ISO 2859/2	Sampling procedures for inspection by attributes – Part 2: Sampling plans indexed by limiting quality (LQ) for isolated lot inspection.
ISO 8402	Quality – vocabulary
ISO 9000	Quality management and quality assurance standards – Guideline for selection and use.
ISO 9001	Quality System – Method for quality assurance in design/development, production, installation and servicing.
ISO 9002	Quality System – Model for quality assurance in production and installation.
ISO 9003	Quality System – Model for quality assurance in final inspection and test.
ISO 9004	Quality management and quality system elements – guidelines.

ANSI

(N.B. ASQC = American Society for Quality Control)

ANSI/ASQC A1	Definitions, Symbols, Formulas and Tables for control charts.
ANSI/ASQC A2	Terms, symbols and definitions for acceptance sampling involving the percent or proportion of variant parts in a lot or batch.
ANSI/ASQC A3	Quality systems terminology.
ANSI/ASQC B1, B2, B3	Guide for quality control charts. Method of analyzing data and controlling quality during production.
ANSI/ASQC C1	General requirements for a quality program.
ANSI/ASQC E2	Guide to inspection planning.
ANSI/ASQC Q90	Quality management and quality assurance standards – guidelines for selection and use.
ANSI/ASQC Q91	Quality systems – Model for quality assurance in design/development, production, installation and servicing.

ANSI/ASQC Q92	Quality systems – Model for quality assurance in production and installation.
ANSI/ASQC Q93	Quality systems – Model for quality assurance in final inspection and test.
ANSI/ASQC Q94	Quality management and quality system elements – Guidelines.
ANSI/ASQC S1	An attribute skip-lot sampling program.
ANSI/ASQC Z1.4	Sampling procedures and tables for inspection by attributes.
ANSI/ASQC A1.9	Sampling procedures and tables for inspection by variables for percent nonconformance.
ANSI/ASQC Z1.15	Generic guidelines for quality systems.

Metrology

BSI

BS 5233	Glossary of terms used in metrology.
BS 5781	Measurement and calibration systems. (Consists of 2 parts)
PD 6461	Vocabulary of metrology
	Part 1: Basic and general terms (international)
	Part 2: Vocabulary of legal metrology fundamental terms.

JIS

JIS C1803	General rules for defining expression of the performance of industrial process measurement and control equipment.

ISO

(N.B. OIML = International Organization of legal metrology)

OIML D1.16	Principles of assurance of metrological control.
OIML D1.0	Vocabulary of legal metrology.

ANSI

ANSI B89.6.2	Temperature and humidity environment for dimensional measurement.

Laboratory Testing and Accreditation

BSI

BS 6460	Specification of the general requirements for the technical competence of testing laboratories.
BS 5781	Measurement and calibration systems – Specification for system requirements.

ISO

ISO/IEC Guide 16	Code of Principles on third party certification systems and related standards.
ISO/IEC Guide 23	Methods of indicating conformity with standards for third-party certification systems.
ISO/IEC Guide 25	General requirements for the technical competence of testing laboratories.
ISO/IEC Guide 28	General rules for a model third-party certification systems for products.
ISO/IEC Guide 38	General requirements for the acceptance of testing laboratories.
ISO/IEC Guide 39	General requirements for the acceptance of inspection bodies.
ISO/IEC Guide 43	Development and operation of laboratory proficiency testing.

ANSI

ANSI/UL 1262	Laboratory equipment.
ANSI/ASME SPPE–2	Accreditation of testing laboratories for safety and pollution prevention equipment used in offshore oil and gas operations.
ANSI/ASQC M1	Calibration systems.
ANSI/ASQC Q1	Generic guidelines for auditing of quality systems.

Lists of publications available in support of the UK National Quality Campaign

These publications were developed and published by the Department of Trade and Industry U.K. in support of the National Quality Campaign (The United Kingdom Government published a policy document entitled 'Standards, Quality and International Competitiveness' in 1982 and this statement of Government commitment to a national policy on standards and quality led to the subsequent U.K. National Quality Campaign. The document makes excellent reading and is available from HMSO, London U.K.]

(1) 'Getting to Grips with Quality' (lists videos, booklets, leaflets ... etc available on the subject of standards and quality)

e.g. (i) 'Quality Counts'

(ii) 'The Case for Quality'

(iii) 'Adult Training'

(iv) 'Quality Circles'

(v) 'Problem Solving for Operations'

(vi) 'Quality Cost'

(vii) 'Company-wide Training Programmes Systems and Attitudes'

(viii) 'Metrology'

(ix) 'Statistical Quality Control'

(x) 'Certification – A Guide for Chief Executives'

(xi) 'Accreditation – What's In It for You'

(xii) 'BS5750 – A Positive Contribution to Better Business' ..... etc.

(2) 'Register of Quality Assessed UK Companies'

(3) 'Directory of Quality Training and Education in the UK' (published by the Institute of Quality Assurance)

(4) 'The National Quality Information Centre' (Operated by the Institute of Quality Assurance)

List of Institutions, Societies and other Organisations associated with quality and standards

1. International Standards Organisations (ISO)
   ISO Central Secretariat
   Case Postale 56
   CH-1211 Geneve 20
   Switzerland

2. International Electrotechnical Commission (IEC)
   P. O. Box No. 131
   3 rue de Varembe
   1211 Geneva 20
   Seitzerland

3. British Standards Institution (BSI)
   2 Park Street
   London W1A 2BS
   United Kingdom

4. The Institute of Quality Assurance
   54 Princes Gate
   Exhibition Road
   London SW7 2PG
   United Kingdom

5. American National Standards Institution (ANSI)
   1430 Broadway
   New York NY 10018
   USA

6. American Society for Quality Control (ASQC)
   230 West Wells Street, Suite 700
   Milwaukee W1 53203
   USA

7. European Organisation for Quality Control (EOQC)
   Bern
   Switzerland

List of HOKLAS Publications 1988

HOKLAS 001	HOKLAS Background & Policy Document "The Introduction of a Laboratory Accreditation Scheme in Hong Kong".	Document for internal use only
HOKLAS 002	HOKLAS Formal Regulations "Non-Technical Requirements for Accredited Laboratories in Hong Kong".	
HOKLAS 003	HOKLAS "Technical Criteria for Laboratory Accreditation".	
HOKLAS 004	HOKLAS "Guidelines for Preparation of a Laboratory Quality Control Manual".	
HOKLAS 005	HOKLAS "Application Form for Laboratory Accreditation".	
HOKLAS 006	HOKLAS "Schedule of Laboratory Accreditation Fees".	
HOKLAS 007 (Proposed)	HOKLAS "List of Potentially Available Calibration Devices in Hong Kong".	Document for internal use only
HOKLAS 008	HOKLAS "Guide for Hong Kong Assessors".	Restricted circulation
HOKLAS 009	HOKLAS "Directory of Accredited Laboratories in Hong Kong".	
Publicity Brochure	HOKLAS "Outline of the Aims and Modus Operandi of HOKLAS".	

Paper No. 4

Towards an International Standard

Speaker: Mr. C. W. Li, Manager
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TOWARDS AN INTERNATIONAL STANDARD

1. Introduction

No matter how good is the performance of an electrical product, it has to fulfil certain "Standards" before it can be marketed in certain countries, especially the fully developed industrialised countries, like USA, UK, Germany and the Scandinavian countries. If the product found not bearing the specific approval mark of the country to be imported, or the importer cannot show the certificate of compliance of the national standard, the whole shipment can be held and no marketing is allowed.

For instance, if an exporter wants to export a radio controlled toy car with only a few transistors to USA, it is under control of Section 2.803 of the "Code of Federal Regulations" Tile 47 (FCC Regulations). The regulation states:

"In the case of a radio frequency device, which, in accordance with the rules in this chapter must be type approved, type accepted, certificated or notified prior to use, no person shall sell or lease, or offer for sale or lease (including advertising for sale or lease) or import, ship or distribute for the purpose of selling or leasing or offering for sale or lease, any such radio frequency device, unless, prior thereto, such devices shall have been type approved, type accepted, certificated or notified as the case may be ....."

In case of mains operated device, for example, a personal computer, it has to comply with the Safety Standard also apart from the radio frequency interference control (RFI) for marketing in USA, Germany etc.

Therefore, it can be imagined that there are how much difficulties to the designers for designing a up-to-standard electrical and electronics product.

2. Road to Standardization and Harmonization

2.1 ISO – International Standards Organization

The International Standards Organization (ISO) was founded in 1947.

The ISO members are representative of each nation's standardization activities, and have agreed to abide by the ISO's constitution and Rules of Procedure.

Today ISO is comprising the national standards bodies of 89 countries. The object of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services.

The scope of ISO covers standardization in all fields except electrical and electronic engineering standards, which are the responsibility of the International Electrotechnical Commission (IEC).

2.2 IEC – International Electrotechnical Commission

The IEC was founded in 1906 as the result of a resolution passed by the chamber of Government Delegates to the Saint Louis International Electrical Congress of 1904. The resolution stated that "steps should be taken to ensure the cooperation of the technical societies of the world by the appointment of a representative commission to consider the question of standardization of the nomenclature and ratings of electrical apparatus and machinery."

In 1947, the IEC became affiliated with the ISO. It is now a well-known international organization covering almost every aspect of electrical standardization. In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between IEC recommendations and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

The IEC now has members from over 40 countries, 70 technical committees and 100 subcommittees.

Different IEC Standards are published by different TC (Technical Committees), e.g.

TC12, "Radio-communication," Sub-Committee 12A, "Radio Receiving Equipment," which has prepared Publ. 65 and Publ. 106.

TC61, "Safety of Household Electrical Appliances," which has prepared Publ. 335.

TC74, "Safety of Data Processing Equipment and Office Machines", which has prepared Publ. 380.

There is a special committee under IEC known as CISPR (Comite International Special des Perturbations Radioelectriques) founded in 1933.

The aim of CISPR is to promote international agreement of the aspects of radio interference, thereby facilitating international trade. CISPR has published many publications on radio interference which set out the limits for interference caused by various electrical and electronic products.

2.3 CENELEC (Comite European de Normalisation Electrotechnique)

In Western Europe an organization on electrotechnical standardization abbreviated CENELEC has been founded.

The CENELEC provides the following aims:

1). To harmonize the national electrotechnical standards of the member countries.

2). To remove trade barriers which may result directly or indirectly from the operation of national marks indicating agreements with the Standards of the members – countries (e.g. approved marks).

For example, the British Standard BS6004 "PVC-insulated cables (non-armoured) for electric power and lighting" has taken into account in its 1984 edition the CENELEC Harmonization Document HD21.S2. In this new edition of the British Standard, harmonized code designations are given, and the requirements are in conformity with those of all countries which accept the basic principles of harmonization in accordance with the requirements of CENELEC.

2.4 EEC (European Economic Communities)

The EEC (European Economic Communities) is using the harmonization documents published by CENELEC directly, as their "EEC directives".

The aim of the EEC is to facilitate the exchange of goods within the European Common Market and to recommend the harmonization of national rules and regulations. The "EEC directives", which is a harmonised document, shall be incorporated in the national legislation. Up to now only a few regulations have been harmonized, but the tendency is that more harmonization will take place.

For example, the UK introduced the Wireless Telegraphy (Control of Interference from Household Appliances, Portable Tools etc.) Regulation 1978 to implement the EEC Directive No. 76/889/EEC. A person who fails to comply with the requirements of these Regulations may be served with a notice under section 11 or 12 of the Wirless Telegraphy Act 1949 and any person who contravenes the provisions of such a notice shall be guilty of an offence under that Act. However, on the other hand, the Directive states that "Member States may not prohibit or prevent the placing on the Market or use of equipment on grounds relating to radio interference, if such equipment meets the requirements of this Directive".

2.5 C B Scheme (IEC + CEE = IECEE)

For the purpose of facilitating international trade and the work in the various testing laboratories, a scheme has been established, participation in which is based on the principle of mutual recognition of test results. This schemes originally operated by the CEE (International Commission for Conformity Certification of Electrical Equipment), is now integrated in the IEC as the Scheme of the IECEE for Recognition of Results of Testing to Standards for Safety of Electrical Equipment (CB Scheme) under the IEC System for Conformity Testing to Standards for Safety of Electrical Equipment (IECEE).

3. Conclusions

Standardization and harmonization is a world-wide trend, though the progress is slow. However, due to the national difference in supply voltage, difference in language and custom, 100% harmonization is nearly impossible.

The work of IEC has been proven in the past to be very successful. Therefore, Hong Kong should partiicipate more in the activities of IEC, so that the industry of Hong Kong can have more information about new standards and proposals and the trends in the international standardization work.

International Electrotechnical Commission

Bulletin

Volume XVIII
No. 95 – September 1985

News from the International Electrotechnical Commission

IEC + CEE = IECEE

To facilitate international trade and simplify the work of testing laboratories in various countries, a scheme was established many years ago based on the mutual recognition of test results as a basis for certification at national level. This scheme, known as the CB Scheme, was originally operated by the Commission for Conformity Certification of Electrical Equipment (CEE). It has now been integrated in the IEC under the IEC System for Conformity Testing to Standards for Safety of Electrical Equipment (IECEE).

The System is based on the use of specific IEC standards for safety of electrical equipment, although CEE standards still in use in certain member countries may continue to be used as the basis for CB test certificates for some time. Up to now almost 7000 CB test certificates have been issued within the CEE for categories of equipment including: lampholders, fence controllers, plugs and socket-outlets, motor-operated appliances, vacuum cleaners, sewing machines, washing machines, lawn mowers, portable tools, luminaires, etc.

The benefits of the IECEE System to industry and users are:

1) The manufacturer can produce electrical equipment that conforms to an international standard (IEC), then obtain a CB test certificate together with a test report, which facilitates certification in CB member countries which adhere to the standard concerned.
2) The equipment can be produced in larger quantities because of the bigger international market that can be served.
3) The user can buy standardized equipment complying with international safety requirements at attractive, competitive prices.

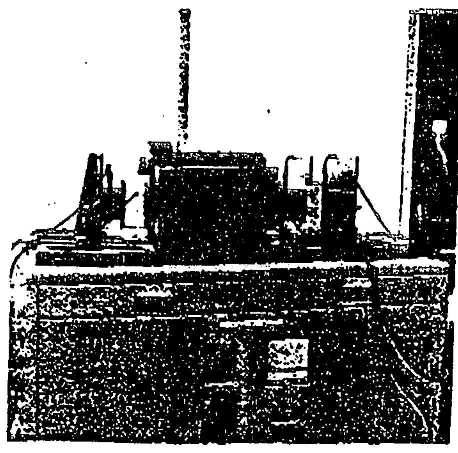
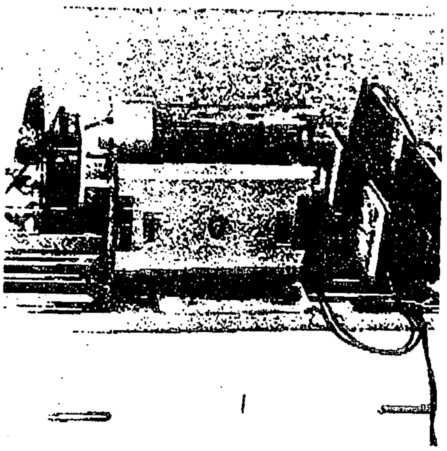
The integration of the CEE into the IEC, settled at the meeting of the IEC Council in Montreal in May 1985, followed by the dissolution of the CEE at its last Plenary Meeting in Copenhagen, September 1985, crowns a long co-operation between the two organizations.

The forerunner to the CEE was founded in Berlin on 14th and 15th April, 1926, under the name of IFK (Installationsfragen-Kommission), to establish safety specifications for electrical installation equipment.

The first subjects to be discussed in the IFK were specifications for switches, plugs, and socket-outlets.

Reference to the IEC was first made in 1930 in the final draft specification for radio receiver sets and amplifiers.

An enquiry among member countries concerning the introduction of IFK specifications showed that some countries had switched over to IFK specifications nearly completely,


The CB Testing Laboratories have been checked to ensure that test facilities available are suitable for the CB Scheme. (Photo KEMA, Arnhem.)

while other countries had adopted them to a lesser extent. The specifications were sometimes criticized because too many construction requirements had been introduced, and in some cases suitable tests were lacking. But it was stressed that uniformity of specifications in the different countries was the basic condition for the introduction of a test mark.

In 1946 the name of the IFK was changed to "International Commission for the ruling and checking of Electrical Equipment", abbreviated CEE, and the following resolution was accepted: "The International Commission for the ruling and checking of Electrical Equipment (CEE) is composed of the bodies which in each and every country, in the interest of the layman, especially with regard to his safety, issue rules and regulations for electrical equipment (wiring, accessories and appliances) and check the fulfilment of such rules and regulations."

In 1948, an agreement between the CEE and IEC formalized their co-operation. The agreement took into account the fact that the IEC is an international body for standardization in the electrical field, whereas the CEE was a regional body dealing with standardization exclusively in the interest of safety. The agreement further stipulated that the IEC National Committees would endeavour:

1) to establish close relations with the CEE national representatives,
2) to improve the exchange of information,
3) to attempt to bring the CEE recommendations into line with those of the IEC.

In 1951, complete agreement with the IEC on specifications for mains-operated radio receivers was reached, and, to avoid double cost by printing a separate CEE publication, it was decided in 1952 that IEC Publication 65: Safety requirements for mains operated electronic and related apparatus for household and similar general use, would be the second edition of CEE Publication 1.

In 1958, the IEC sub-committee on safety regulations stated in a report to the Committee of Action "that the most practicable course of action for the IEC, as far as safety regulations for domestic appliances was concerned, would be to collaborate with the CEE in the preparation of CEE specifications and to adapt or, to adopt them for use in a wider international sphere". Arrangements were made to exchange between the CEE and the IEC final drafts of their work on subjects of mutual concern in relation to safety.

At the request of the French National Committee of the CEE, in 1961, it was decided to deal with directives for performance tests after the revision of CEE Publications 10 and 11 for household appliances. In May 1964, the IEC took the first steps for starting such work, resulting in the creation of TC 59 and a large number of specialized sub-committees.

In May 1966 the procedure to be followed when considering IEC recommendations which could lead to joint IEC-CEE specifications was discussed. A general agreement was reached that there should be complete harmonization between the publications of both commissions and that duplication of work should be avoided. The certification scheme could be based on IEC publications endorsed by the CEE. Furthermore, the CEE was to receive a copy of all IEC documents dealing with subjects of interest to the CEE, and IEC and CEE publications on the same subject, even if fully identical, could be issued separately, and, finally, the CEE would be officially represented in IEC meetings dealing with subjects also of concern to the CEE.

As time went by, the importance of an even closer co-operation between the two organizations became evident. A study group was established within the CEE, to prepare a long-term policy of the CEE. It was recommended that all specification-writing should be done by the IEC. It was further anticipated that the CEE should run schemes for certification and marking and that the IEC should make specifications for this purpose available, which should then be endorsed by the CEE in order to form the basis for the work of the CEE. A wording for the long-term policy of the CEE was agreed upon as follows:

1) To operate a scheme for certification and for marking to indicate that electrical equipment intended to be used in homes, offices and similar locations complies with particular safety specifications.
2) To ensure that test specifications suitable for certification purposes are available to the largest possible extent by applying the endorsement procedure to IEC publications.

The final step towards complete co-operation was taken when the CEE, as a logical consequence of the long-term policy, asked the IEC Council if it was interested in an arrangement whereby the CEE would be integrated within the IEC. This integration is now a fact, which means that the certification activities are now under the authority of the IEC.

In addition, the activities of the CEE Committee of Testing Laboratories (CTL), which is a forum where representatives of the various testing laboratories can discuss and propose solutions to problems encountered in conjunction with testing, will also be continued in the IEC.

The specific IEC standards for use in the IECEE System should include clauses permitting and simplifying conformity testing. Attention should be paid to specifying testing procedures which are in line with basic safety standards or group safety standards or to make reference to these standards.

The ever-increasing size and complexity of standards is a matter of grave concern. The increase in time required to test appliances as well as the ever-growing number of necessary control devices resulting from the continuous growth in the number of requirements in the standards, make conformity testing more complicated and costly.

Whereas standards writing is a continuous commitment to ensure that adequate requirements are introduced to keep up with new designs and advancing technology, by the same token attention should be paid to remove requirements that are no longer necessary or are outdated. In addition, there should be a better compatibility of requirements between different standards. When new standards are being prepared or existing standards amended, the IEC committees concerned should consider at every step keeping requirements and test methods as brief and coherent as possible and to consider rationalization of—or amalgamation with—existing requirements. In this context IEC Guide 104 and the work done in ACOS plays an important role.

Table 1. PVC-insulated, non-sheathed general purpose cable, 450/750 V, single-core

(a) Rigid conductor

NOTE 1. The cables may be suitable for voltages up to 1000 V a.c. or up to 750 V to earth d.c. (see appendix A).

NOTE 2. Cables having conductor sizes smaller than 1.5 mm² are to be found in table 2.

Harmonized code designation

Solid conductor: H07V–U.
Stranded conductor: H07V–R.

Construction

Annealed copper conductor, class 1 solid conductor and class 2 stranded conductor, as shown below.
PVC insulation type TI1.

Colours for core identification. Green/yellow, blue or other colours (see 6.3).

Nominal cross-sectional area of conductor	Class of conductor	Radial thickness of insulation	Mean overall diameter (upper limit)	Minimum insulation resistance at 70 °C
mm²		mm	mm	MΩ·km
1.5	1	0.7	3.3	0.011
1.5	2	0.7	3.5	0.010
2.5	1	0.8	3.9	0.010
2.5	2	0.8	4.2	0.009
4	1	0.8	4.4	0.0085
4	2	0.8	4.8	0.0077
6	1	0.8	4.9	0.0070
6	2	0.8	5.4	0.0065
10	1	1.0	6.4	0.0070
10	2	1.0	6.8	0.0065
16	1	1.0	7.3	0.0058
16	2	1.0	8.0	0.0050
25	2	1.2	9.8	0.0050
35	2	1.2	11.0	0.0040
50	2	1.4	13.0	0.0045
70	2	1.4	15.0	0.0035
95	2	1.6	17.0	0.0035
120	2	1.6	19.0	0.0032
150	2	1.8	21.0	0.0032
185	2	2.0	23.5	0.0032
240	2	2.2	26.5	0.0032
300	2	2.4	29.5	0.0030
400	2	2.6	33.5	0.0028
500*	2	2.8	37.0	0.0028
630*	2	2.8	41.0	0.0025

*National type.

(b) Rigid copper-clad aluminium conductor

NOTE. The cables may be suitable for voltages up to 1000 V a.c. or up to 750 V to earth d.c. (see appendix A).

National type

Construction

Plain annealed copper-clad aluminium conductor, class 1 solid conductor and class 2 stranded conductor as shown below.

PVC-insulated type TI1.

Colours for core identification. Green/yellow, blue or other colours (see 6.3).

Nominal cross-sectional area of conductor	Class of conductor	Radial thickness of insulation	Mean overall diameter (upper limit)	Minimum insulation resistance at 70 °C
mm²		mm	mm	MΩ·km
1.5	1	0.7	3.3	0.011
2.5	1	0.8	3.9	0.010
4	2	0.8	4.8	0.0077
6	2	0.8	5.4	0.0065
10	2	1.0	6.8	0.0065
16	2	1.0	8.0	0.0050

(c) Flexible copper conductor

NOTE 1. The cables may be suitable for voltages up to 1000 V a.c. or up to 750 V to earth d.c. (see appendix A).

NOTE 2. Flexible cables smaller than 1.5 mm² are to be found in BS 6500.

Harmonized code designation. H07V–K.

Construction

Annealed copper conductor, class 5 flexible conductor.

PVC-insulation type TI1.

Colours for core identification. Green/yellow, blue or other colours (see 6.3).

Nominal cross-sectional area of conductor	Radial thickness of insulation	Mean overall diameter (upper limit)	Minimum insulation resistance at 70 °C
mm²	mm	mm	MΩ·km
1.5	0.7	3.5	0.010
2.5	0.8	4.2	0.009
4	0.8	4.8	0.007
6	0.8	6.3	0.006
10	1.0	7.6	0.0056
16	1.0	8.8	0.0046
25	1.2	11.0	0.0044
35	1.2	12.5	0.0038
50	1.4	14.5	0.0037
70	1.4	17.0	0.0032
95	1.6	19.0	0.0032
120	1.6	21.0	0.0029
150	1.8	23.5	0.0029
185	2.0	26.0	0.0029
240	2.2	29.5	0.0028

Paper No. 5

Modern Electrical Test Instruments

Speaker: Mr. Barry Clegg, Business Development Manager, BICC, H.K. Ltd.

MODERN ELECTRICAL TEST INSTRUMENTS

1. Summary

1.1 The need for modern electrical test instruments is examined with respect to:

1.2.1 What electrical systems are to be tested. The systems and their parts are defined.

1.2.2 What tests need to be carried out, why, for what reasons and when.

1.2.3 The instruments currently available, how and why they have been developed and how they apply to different parts of a system and different phases of testing.

1.2 Instruments and their application are described as applied to:

1.2.1 Testing

1.2.2 Monitoring

1.2.3 Routine Maintenance

1.2.4 Checking faulted systems

1.2.5 Location of faults

1.3 These descriptions are supported by detailed appendices and reference, where necessary or relevant, to historical aspects such as the derivation of an instrument or method.

1.4 No formal conclusions are necessary, nor are any made. However, comment and opinion are given regarding the usefulness of the instruments discussed together with speculation on the influence they have had or could have on the way systems are run and maintained.

2. Introduction

2.1 Before considering particular test instruments we should specify why we need them. This is surely to ensure the smooth and efficient running of an electrical system be it an EHV overhead transmission system, HV underground distribution system or just one L. V. circuit.

2.2 Because no system is perfect it follows that we are investigating failures or potential failures in order to achieve this, i.e. how to prevent them, detect them or rectify them.

2.3 Instruments measure or record quantities or events and we should consider carefully just what quantities and events need to be analysed and what instruments are best suited to measuring and presenting the information.

2.4 The test requirements also need to be defined.

These are: –

2.4.1 To test a system before energising

2.4.2 To monitor a system when running

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GEC HONG KONG

2.4.3 To assist routine maintenance

2.4.4 To check a faulty system

2.4.5 To locate failures.

2.5 The aim is to keep the system running as efficiently as possible and to bring about the speedy restoration of a faulted system.

2.6 Also, it is necessary to define exactly what is meant by "Electrical System". An electrical system is made up of:

2.6.1 Conductor (Busbar, Underground Cable, Overhead Cable or Conductor)

2.6.2 Components and Fittings (eg Joints and Terminations)

2.6.3 Switchgear

2.6.4 Instruments (i.e. permanently installed instruments such as meters and relays).

2.7 It is proposed therefore to look at those modern instruments which are ideally suited or, indeed, designed for testing and monitoring on electrical systems.

In doing this two things are immediately apparent:–

2.7.1 In almost all cases the computer or microcomputer plays a major role in the operationof the instrument or, if not, in its design.

2.7.2 The most innovative and dedicated instruments derive from countries with old, well established and heavily loaded systems containing a great deal of underground cable. These are countries with complex systems, the owners of which have been forced to investigate and solve problems in order to run their systems efficiently, avoid damage and danger to life and be able to constantly renew them in an effective way.

Perhaps the prime example of this is the United Kingdom where the Power Authorities and their related research organisations have been instrumental in identifying and solving many problems.

The bodies concerned are:–

- The Central Electricity Generating Board (CEGB)
- Its research arm: The Central Electricity Research Laboratories (CERL)
- The Distribution Authorities (Area Boards)
- Their reserch arm: The Electricity Council Research Centre (ECRC)

These bodies conceive the idea, carry out research, development and testing and then licence private firms to produce commercially viable instruments.

Many of the instruments considered below were born in this manner.

3. Instrumentsand applications:–

It is proposed to consider the most useful modern instruments related to the applications.

- Testing
- Monitoring
- Routine Maintenance
- Checking (Faulted System)

and

- The Location of Faults and Failures

3.1 Testing:

3.1.1 Prior to energising or re-energising

The basic tests are those which are required to establish the electrical integrity of a system. e.g. Insulation Resistance tests and D.C. Pressure tests for cables and Insulation Resistance tests and A.C. Pressure tests for switchgear.

The features of modern Insulation Resistance testers are:–

- Robustness
- Ease of operation
- Reliability
- Ease of interpretation.

These have been achieved by experience in design allied to computer aided design, assembly and testing techniques.

Examples of the most up-to-date instruments are shown in:–

. Appendix 3a
. Appendix 3b
and . Appendix 3c

Pressure test sets are not considered in detail.

3.1.1 While energised:–

Various phenomena occur at weak points in a system while running, the main ones being overheating and partial discharge.

For instance a bus-bar connection, overhead line joint or fuse carrier may exhibit an initial low contact resistance which produces minor local heating the early detection of which can save a major failure as the heating "runs away" due to the dissipation of energy.

Instruments for detecting this vary from thermal "Guns" with digital temperature readout to sophisticated thermal imaging systems.

Partial Discharge occurs under AC conditions at any weak point, non-homogeneity or discontinuity in a dielectric under stress. (In practical terms say from 3KV upwards).

The whole subject is very complex but, basically, such discharges occur in bursts or continuously on each half cycle and produce frequencies over a very broad spectrum through Audio, Ulltrasonic, R. F. VHF & UHF. They can be detected as electrical signals, electromagnetic signals, ultra-sound and sound.

"Corona" on external surfaces and fittings can also produce detectable minor local heating and, in some circumstances, a visual effect.

Classical Partial Discharge detection equipment functions by connecting electrically to a test object energised from a discharge-free test source and measures and displays very low energy levels.

Tests have normally been carried out in factories and laboratories but, in recent years, significant developments have been made in the rejection of interference which now enable tests to be carried out in un-screened situations and, in some cases, in the field.

. Appendix 3d.

Also, several very practical test systems have been devised which can be applied to energised systems.

These are:–

– The "Hot Stick" developed by CERL (see Appendix 3e)

This ingenious device consists of a light weight ultra sonic detector operating at 23KHz mounted on the end of an insulated fibreglass tube.

The US signal is displayed by a high intensity LED array and can also be heard as an audible signal in stethoscope headphones worn by the operator standing at a safe distance.

The unit can be used up to 11KV or 33KV with the extension.

It is particularly useful in checking HV connections made off in air, for example the stress-relieved shrink down terminations on HV plastic insulated single core cables now in common use in power station auxilliary circuits and oil and petrochemical installations. A badly made off termination can deteriorate to break down in a few months and an ultrasonic check soon after energising can save a costly outage.

– The "Corona Gun" developed by CERL (see Appendix 3f)

Also a detector of ultra sonic emissions, the Corona Gun embodies a parabolic dish which focuses the signal onto a 23KHz transducer. A telescopic sight is also incorporated making it possible to target discharge sites on EHV outdoor equipment such as insulators and bushings up to a range of 75M.

Again, there is sudible and visual indication of the signal.

Thus faults can be identified at an early stage allowing remedial work to be undertaken before more costly breakdowns occur.

– The "TEV" discharge locator, developed by ECRC (see Appendix 3g)

Incipient insulation faults in high voltage metalclad switchgear and terminations is accompanied by discharge activity, increasing till breakdown occurs.

The Transient Earth Voltage (TEV) discharge locator is the result of several years work by the Electricity Council Research Centre, UK into the detection of these on 'live' systems.

As shown in the illustration, discharges cause a transient voltage depression on the HV conductor which is compensated by a transient of equal magnitude and opposite polarity impressed on the inner skin of the earthed metal cladding.

These transients travel along the inner surface of this metal only 'seeing' the characteristic impedance ahead, and exit onto the outer metal skin at any joint such as a gasketed joint or box cover.

Two capacitively coupled probes are used to pick up these signals which are presented to the operator by audio and visual means, and their relative magnitude is indicated on a liquid crystal display.

The device is simple and easy to use on equipment in service and provides a means of routine mass screening of switchgear without the need for outages or Sanctions for Test.

Therefore dangerous occurrencies can be avoided and proper programming of equipment refurbishment effected, thus safely extending the life of older equipment.

3.2 Monitoring

Basically, system monitoring can be divided into three main categories

- The routine measurement of quantities.
- The permanent monitoring of quantities, levels and events with resultant action.
- The permanent monitoring of quantities, levels and events for subsequent analysis.

3.2.1 Routine measurement of quantities.

Into this cateogry fall the standard measurements of Voltage. Current and Energy etc.

3.2.2 Permanent monitoing for system protection:–

This includes event and level detectors and protection relays which are called upon to send signals for alarm or trip-off. Modern protection relays are very complex and sophisticated solid state instruments and demand a new approach to relay testing. (see section 4 – routine maintenance).

3.2.3 System Disturbance Recorders.

In this cateogry come:–

– Straightforward chart recorders for voltage or current.

– Small portable computer controlled mains recorders. An example of this type is the PDA1 in Appendix 3h.

This unit is a small state of the art computer controlled device with integral printer which is capable of detecting and printing out:–

– High and low average voltage

– Sags and surges in voltage

– Spikes and spike bursts

– Drop outs

– Power cuts

– High and Low frequencies

– HF noise

Any of these disturbances can cause serious problems in process controls or production lines and can generate corrupt data in computer installations.

A record, either as a summary or a complete account can be viewed on the instrument's LCD or in hard copy from the integral printer.

Another type of mains disturbance recorder has been developed by the ECRC for the very special purpose of monitoring 'Flicker" on mains.

– see Appendix 3i.

Visible Flicker effects on Tungsten Filament Lamps are produced by voltage variations in the range 1 to 25 Hz and when these variations are of the order of 10Hz annoying flicker can be caused by amplitude modulations of less than 1%. Normally the cause of flicker is rapid thyristor switching of large loads such as arc furnaces and the remedies are the provision of separate supply networks and or the installation of compensators both of which are extremely expensive.

The instrument is based on an extremely powerful 16 bit computer and is capable of measuring and analysing:–

– Severity, awareness and perception of Flicker on a constantly monitored basis to the IEC (U.I.E.) international standard.

– Harmonics; single channel up to 31st and dual channel up to 23rd. Measurement is by Fast Fourier analysis and all harmonics are displayed simultaneously but may be analysed individually.

– Voltage step changes; The RMS voltage is compared, cycle by cycle, with a rolling 30 seconds average.

All data displayed in any of these modes may be optionally recorded on diskette to provide up to several weeks of data storage and further analysis either by printout or graphically.

Monitoring the supply for Flicker can save the vast amounts of money involved in providing separate or compensated supplies.

Indeed, as shown in Appendix 3i, the Flicker monitor can also be used as a control device to adjust the furnace operating point so that the level of flicker produced does not exceed a pre-set limit.

Finally there is the sophsticated Power System Disturbance Recorder, a multichannel device which monitors voltages, currents and events on High Voltage Power Systems.

Modern instruments are based on microprocessors which acquire and store the transient data and control the transmission or printing out of the information. Appendix 3k gives the specifications of current models together with examples of printouts showing recordings of occurrencies on transmission systems.

The IMS family of disturbance recorders is a new range of solid state eight bit & twelve bit disturbance recorders of a modular construction designed to provide reliable cost effective solutions to the many & varied disturbance recording applications which exist in today's power transmission industry. However as well as offering all the regular facilities currently available in this field, a new range of options has been added to greatly enhance the product and to provide additional flexibility and information for the power engineer.

Features Include

– Reliable solid state microprocessor electronics.

– Up to sixteen analogue and thirty-two event channels in one recorder module.

– Analogue signals digitised with 8 bit or 12 bit resolution depending on application.

– A recorder triggered from any combination of analogue or event channels.

– Record length programmable from the keyboard.

– Various digital sampling rates available.

– Analogue signal scaling on the printout, programmable from the keyboard.

– High quality, high resolution thermal printer for hardcopy.

– Text string assignable to each analogue and event input.

– Ability to summarise fault type, duration and severity.

– Distance to fault printout (optional).

– Permanent data storage on magnetic tape (optional).

– Remote serial communication facilities.

– Remote data collection and replay system available.

It will be seen that great advances have been made since the not too distant days of the electro-mechanical, multichannel pen recorder operating in real time.

Also, because of the sophisticated analyses now possible new avenues have been opened up, for example:–

– By using complex algorithms, the data acquired can be used to forecast distance to fault.

– The analogue and event data has a direct bearing on decisions regarding the maintenance of a system. For example, circuit breakers are at present maintained on a routine basis based on an arbitrary interval or on numbers of operatons. The above data can give accurate information on the actual time of clearing of the circuit breaker and the current it was breaking thus indicating the real wear.

– Date from an actual fault can now be memorised and fed into the automatic relay test sets (ref 4.3) so that real quantities can be fed to a relay to see how it would (or should!) have responded in the field.

4. Routine Maintenance:–

Testing related to routine maintenance can be divided into:

4.1 Testing prior to re-energising (covered in 3.1.1.)

4.2 Testing during switchgear maintenance.

4.3 The testing of Protection Relays

As mentioned earlier Relay Testing requirements have changed significantly in recent years due to the increasing sophistication of Protection Relays, particularly Distance Relays on EHV systems which are now solid state. Each relay is very complex and contains a large number of devices thus making it essential to carry out maintenance more regularly than, perhaps, every two years. Using conventional test equipment, however, it can take almost a whole day to test a relay and vital high voltage lines and plant can not be taken out of service for this length of time at regular intervals.

Computerised relay test sets are now available, developed in conjunction with the UK CEGB which can test even complex relays automatically and quickly so that the HV circuit can be left on load relying on Second Main and Back-up Protection for a short tiime.

As shown in Appendix 4 there are two equipments specially designed to allow fully automatic testing of protection relays. The one in figure 1 is for the complex types of relay found on E.H.V. transmission systems such as distance or phase comparison whilst that shown in figure 2 is for the simpler relays, overcurrent etc., found on distribution and industrial power systems.

Many benefits can be obtained from the use of such computerised equipment:

Rapid testing; a full scheme distance relay can be tested in less than 15 minutes.
More efficient use of manpower resources; as a skilled tester is able to perform

Rapid testing; a full scheme distance relay can be tested in less than 15 minutes.

More efficient use of manpower resources; as a skilled tester is able to perform more tests in a given time or, conversely, less skilled personnel can be used with the test results being passed back to a central location for evaluation.

The short interval of time for which a relay is out of service for testing means that the primary plant can be left in service without significantly increasing the risk of non operation due to a system fault. Thus can lead to greater flexibility both in the planning and the execution of routine protection relay testing programmes.

As the test procedure is fixed by the initial programming of the equipment the testing is done to a common standard with the possibility of human induced errors and inaccuracies being kept to a minimum.

The logistics of relay testing can be eased as just one type of test set can be used to test the many different types of relay used.

The basic requirement for any relay test equipment is that the simulated power system quantities are changed until the required response of the relay is found. In normal test equipment the signals are typically derived from three-phase mains inputs, using variable transformers, etc., and manually adjusted until the relay operates.

In the new automatic test sets, the test waveforms are produced mathematically by the built-in computer. Digital to analogue converters are then used to convert these numerical waveforms into low level voltages, which are used to drive power amplifiers. These produce the necessary level of current and voltage to operate the relay. At the same time, the outputs of the relay are monitored by the computer so the effect of the injection is noted. Suitable strategies are used to change the injected signals until the required relay response is obtained. The equipment then displays on a CRT the results of the test, typically as shown in figures 3 and 4.

The production of test signals by a combination of mathematical and electronic techniques allows complex current and voltage signals to be readily obtained. Thus this type of test equipment can more closely simulate power system disturbances than traditional test equipment. Figure 5 shows signals produced by the equipment in which a D.C. offset is included in the current signal. Varying amounts of harmonics can also be produced and superimposed on the fundamental as shown in figure 6.

5. Checking a Faulty System

The various monitoring instruments already described, together with the protection relays will identify problems and disconnect the faulted zone when necessary.

Diagnosis differs significantly depending upon whether the faulted part of the system is:

. Overhead line
. Switchgear
or . Underground cable

5.1 Overhead Line

A basic diagnosis has already been accomplished by relay indications and more detailed diagnosis (and location) is normally carried out by inspection.

5.2 Switchgear

Again, the location and extent of trouble on switchgear is often obvious.

5.3 Underground Cable

The diagnosis (and subsequent location) of faults on underground cable system is much more difficult and can be considered an art as much as a science.

Diagnosis should be carefully carried out in a logical manner and all results tabulated. Tests should be made to establish the insulation resistance and continuity of the cable cores and all paths, i.e. core to shealth/earth, core-to-core, sheath to earth etc, should be checked and recorded.

The instruments required for this are: –

. Ohmmeter
. I. R. Tester
. D. C. Pressure test set
. Pulse-echo test set (See Section 6, Fault Location)

5.3.1 Ohmmeter

Appendix 5 carries information on a range of modern analogue/digital multimeters ideally suited for field diagnosis. It is important that such an instrument be used initially. It has a low test voltage of a few volts which will produce a true diagnosis prior to the application of a Pulse Echo Set (which also has a low voltage pulse).

5.3.2 Insulation Resistance Tester

These have higher test voltages than ohmmeters and this is necessary when the fault is not evident at lower test voltages and, moreover, when high voltage techniques may be employed in the ensuring fault location (See Section 5).

A large range of I. R. testers is shown in Appendices 3a, b & c This includes instruments, "Hand Cranked" and "Press-button", with voltages from 50V to 5kV.

The choice of tester is largely decided by the type of cable to be tested. For instance, a short L.V. cable can be adequately checked with a small hand held "press-button" tester delivering 50–1000v, whereas a heavy duty tester capable of charging up a long cable and testing high resistances would be used on long HV and EHV cable. Test voltages of 5kv are often required. (Appendix 3c)

5.3.3 D.C. Pressure Test Set

Apart from being more normally used for proof-testing or burn-down, a D.C. test set may be required to establish the breakdown voltage of a "Flashing Fault", i.e. a fault which is essentially a gap with a particular voltage threshold.

5.3.4 Pulse Echo Set

This is a pre-location instrument which can nonetheless be very usefully applied during preliminary diagnosis in order to check:–

– See Appendix 6d

. Continuity
. Presence of joints
. Propagation velocity of cable

6. Fault Location

Because of reasons given in 5.1 and 5.2, comments are confined to fault location on Underground Cables.

For general background to this rather complicated subject, Appendices 6a, 6b & 6c have been included. Appendix 6a "Cable Fault Location, a Practical Guide", is a no-nonsense approach to fault location with the emphasis on what instruments or methods suit any particular application within a budget.

Appendix 6b is a brief summary of the origins and current state of the "Impulse Current" method which has revolutionized cable fault location in the last decade.

Finally, Appendix 6c is the definitive article on the Impulse Current Method by its inventor Dr. P. F. Gale.

Again, this method is an example of a development by the ECRC resulting from research into the problems associated with the location of the "Flashing Fault" which was, hitherto, the most difficult type of fault to pre-locate.

Now their pre-location is much more straightforward as the modern Impulse Current sets can memorize a single transient resulting from a surge applied to the cable. Facilities also include cursors for measurement and an on-screen alpha-numeric display to present the trace, parameters and results.

Apart from Resistance Bridges which still have a role to play, the other main method of pre-location is "Pulse Echo".

A Pulse Echo test set sends a low voltage pulse down a cable core which is wholly or partly reflected by any impedance mis-match presented by a joint, open circuit (or end) or fault. The resulting trace is presented on a C.R.T. screen (or in smaller sets), Liquid Crystal Display so that the fault can be recognized and a prelocation measurement made.

Appendix 6d shows a modern Pulse Echo Fault Locator with ranges from 0–30M to 0–15KM and a memory facility for comparing healthy and faulty traces.

Finally, the exact location overground or "Pin-pointing" of the fault is normally carried out with a Surge Generator (see Appendix 6c) which injects a very high energy surge into the cable causing a loud noise at the point of fault. This can normally be detected orverground using a sensitive ground microphone and amplifier.

7. Conclusion

For many years it was the case that the technical standing of the electronics industry at any given time was always such that solutions were available to the problems of the beleaugered Power Engineer but which were rarely forthcoming. This was because the

Electronics engineer and the Power engineer did not communicate as they do now and, though "problem-related research" was carried out, the techniques and components available tended to produce rather cumbersome results.

Nowadays, the Power Engineer not only communicates with his Electronics counterpart but is often qualified in Electronics himself or is well aware of electronic techniques. Furthermore, the microchip and microprocessor have revolutionised research into test instruments for Electrical Systems. This, and the greatly increased awareness of Engineers and Scientists in Research, Manufacture and Distribution have produced some truly remarkable instruments which greatly assist in the running of our Electrical Systems and in getting more speedy tests done within a specified time frame (quantity), but at the same time in assuring higher reliability (quality) of systems energize.

Appendices

Please refer to the following publications:

Appendix 3a: Hegger Insulation tester, T&W/5K/9S, Megger Instruments Ltd.

3b: Megger Digital Insulation Tester 3MD3, T&W/7.5K/2T, Megger Instruments Ltd.

3c: Megger Insulation Testers, SL/5K/9S, Megger Instruments Ltd.

3d: Discharge detector series 800, Type 803, Robbinson Instruments Ltd.

3e: Cerl hotstick Type 762, Robinson Instruments Ltd.

3f: Cerl Corona Gur Type 766, Robinson Instruments Ltd.

3g: TEV discharge Locator Type 646, Robinson Instruments Ltd.

3h: Megger Power Supply Data Recorders, SL/7.5K/12S, Megger Instruments Ltd.

3i: 'Power Master' Power Disturbance Analyser, Basingstoke, Dicoll Electronics Ltd.

5: AVD Digital Multimeters, MP/10K/7R, Thorn EMC Instruments Ltd.

6d: Digital Pulse Echo Cable Fault Locator, BICCOTEST LTD.

Appendix 3j

Foiling flicker – 'Down Under'

Computer technology developed at Capenhurst has travelled half way around the world – to ensure homes in Australia stay brightly lit.

WHEN a newly-installed arc furnace goes into action at the Commonwealth Steel Company's plant at Waratah, New South Wales, the Dicoll PowerMaster will prevent lights flickering for miles around.

The PowerMaster was primarily designed by Capenhurst for the monitoring of disturbances on the electricity mains. At Waratah, however, it will be used for the first time as a control device, to minimise the effect of voltage fluctuations caused by the furnace on the surrounding power supply network.

For Dicoll Electronics, a leading supplier of specialist computer equipment based at Basingstoke, the Australian order was proof of PowerMaster's promising future in world markets. Said Sales Manager, David Thorpe: "We have not sold that many abroad yet because, as with any product, it is wise to create a feeling of confidence in the home market before trying to open up export markets.

"But we have already sold about a dozen systems in the UK and now we are beginning to export as well. We have sold one system to the Egyptian Electricity Authority and we have got a number of tender proposals in from various parts of the world, including Finland and the USSR.

"It is particularly significant for developing nations, which often suffer fairly serious problems with interference to their power supplies. We also foresee the UK market opening up because of the possibility of new legislation."

PowerMaster, the product of a four-year Capenhurst project, is the world's first digital computer system to effectively monitor disturbances on the mains. It is based on a Dicoll microcomputer incorporating an integral visual display unit and is supplied with a 5¼" disk drive and a detachable keyboard.

The equipment is designed to give highly accurate information on the quality of electricity supplies. It will alert industrial plant operators that they are in danger of causing flicker and automatically control the offending plant to prevent it. The system measures and analyses flicker disturbance to a recently-agreed international standard, providing detailed information, at regularly timed intervals, on the severity, awareness and perception of flicker.

Logic controller

Purchasing PowerMaster can bring significant cash savings for both electricity utilities and industrial plant operators. By accurately assessing the quality of the power supply, the need to invest in costly separate power supply networks for flicker-producing equipment or to install static compensators can be reduced or avoided.

PowerMaster can analyse 31 harmonics on a single channel or 23 harmonics on two channels, showing the phase relationship between them. Input readings are scaled to record harmonic currents in equivalent root mean square circuit amps. It also displays voltage changes as the number of voltage steps since the start of the program and as the number of voltage steps during the last minute.

Sydney-based BHP Engineering installed a PowerMaster system as part of its comprehensive redevelopment of the meltshop at the Commonwealth Steel Company's works. The equipment will be used in conjunction with a standard computer interface and a programmable logic controller to adjust the furnace operating point so that the level of flicker produced does not exceed a preset limit.

IMS 8/12 DISTURBANCE RECORDERS

TECHNICAL SPECIFICATION

Recorder

Number of analogue channels:	8 expandable to 16
Number of digital channels:	16 expandable to 32
Sampling rate:	2 kHz up to 4.8 kHz
Resolution:	8 bits or 12 bits
Pre-fault time:	50, 100, 150 or 200 ms
Post-fault time:	250, 500, 750 or 1000 ms
Size of fault buffer:	512 kbytes expandable to 4 Mbyte in blocks of 512 kbytes

Printer

Replay method:	Fixed head thermal printer
Paper width:	222 mm
Paper takeup:	Integral, driven by printer motor
Resolution:	6 dots/mm
Displayed information:	Machine number Fault number Date and time of fault Channel and event trigger mask status Cause of trigger Amplitudes of fault levels Distance to fault

Inputs

Voltage Inputs:	Inputs available up to 110 V rms to give full scale deflection on printed output
Current inputs:	Inputs available up to 15 A rms to give full scale deflection on printed output
Adjustment:	Offset and gain controls for each channel
Interposing Transformers:	Interposing transformers are provided for all analogue channels to provide isolation. Four voltage or current transformers are mounted in one box dimensioned 230mm x 75mm x 75mm. Each box to be mounted external to the IMS 8/12 framework but preferably in the same cubicle.
Event Inputs:	Dry contacts. External battery (110 V) used to supply wetting current (20 mA)
Isolation:	2 kV power frequency between all inputs and case.
Surge withstand capability (SWC):	2.5 kV (1 MHz damped sinewave)
Impulse withstand:	5 kV, 0.5 Joule

Programmability

Membrane keypad:

Built into the transient recorder. Used by the operator for setting up the instrument. Adjustable parameters include:-

Pre-fault time

Post-fault time

Analogue and Event Trigger Mask

Machine Identification

Manual trigger

Set time and date

Set up:	Display current ADC level of each analogue input
Liquid Crystal Display:	7 lines of 32 characters. The time, and machine status will be displayed except when the recorder parameters are being set in which case a menu of options will become available.

<u>Clock</u>

Source:	32.768 kHz crystal
Range:	0.1 seconds to months. Leap years calculated.
Manual setting:	Available from the membrane keypad.
<u>Battery back up</u>	NiCad rechargeable batteries to maintain clock setting and operating parameters during a power supply failure. Batteries automatically re-charged from DC supply.

<u>Alarms</u>

<u>Digital</u>

All outputs available as normally open dry contacts

Output contact rating:	500 mA @ 200 V d.c. 10 W (non reactive)
Output alarms:	Machine triggered Paper low Power supply failure Processor watchdogs

Visible

The following are available as indications on the LCD display:-

Machine triggered (signalled by frozen clock display while recorder transfers information from the slave to the master processor)

Buffer full

Paper low

Printer disabled

Slave watchdog

Analogue triggering

All triggering parameters are set from the keypad and no external hardware is required.

Analogue triggering is available for each channel and may be one of two types. The user can select either a simple level trigger or a rate of change trigger.

Level triggering is available as over or under triggering for voltage and current channels respectively, with threshold selectable from 5% to 95% in steps of 5%.

Rate of change trigger is set as a percentage change of full scale deflection per cycle, settable from 5-50% in steps of 5%.

Optional Extras

i) Cabinet to house IMS 8/12 to convert it to a stand alone, portable unit.

ii) Data transmission facilities via an RS232 link.

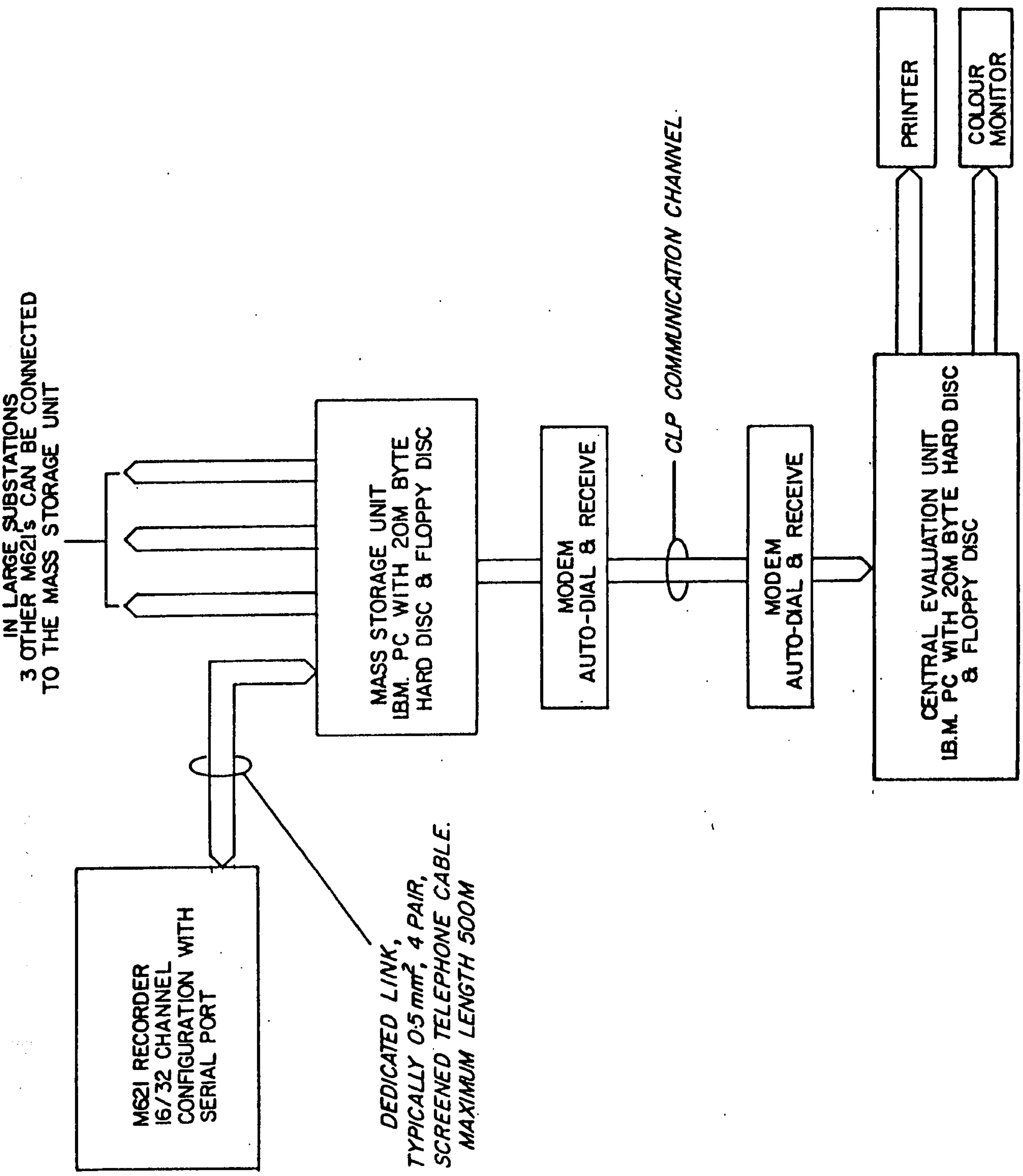


Fig I -SYSTEM DIAGRAM

The General Electric Company of Hong Kong Limited GEC HONG KONG

<<< ME21 MICROSTORE >>>

BICCOTEST CIRCUITS & SYSTEMS DESIGN

```
MACHINE I.D. :- M621 SAMPLE PRINTOUTS
FAULT NO.    :- 0107
DATE         :- 7 MAY 1986
TIME         :- 15:00:00.3
CHANNEL TRIGGER MASK ( 16 - 1 ) :- OFF OFF OFF OFF OFF OFF OFF ON  OFF OFF OFF OFF ON  OFF OFF OFF
EVENT TRIGGER MASK  ( 32 - 17 ) :- OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
                    ( 16 - 1  ) :- OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
CAUSE        :- OVER TRIGGER ON CHANNEL 04
```

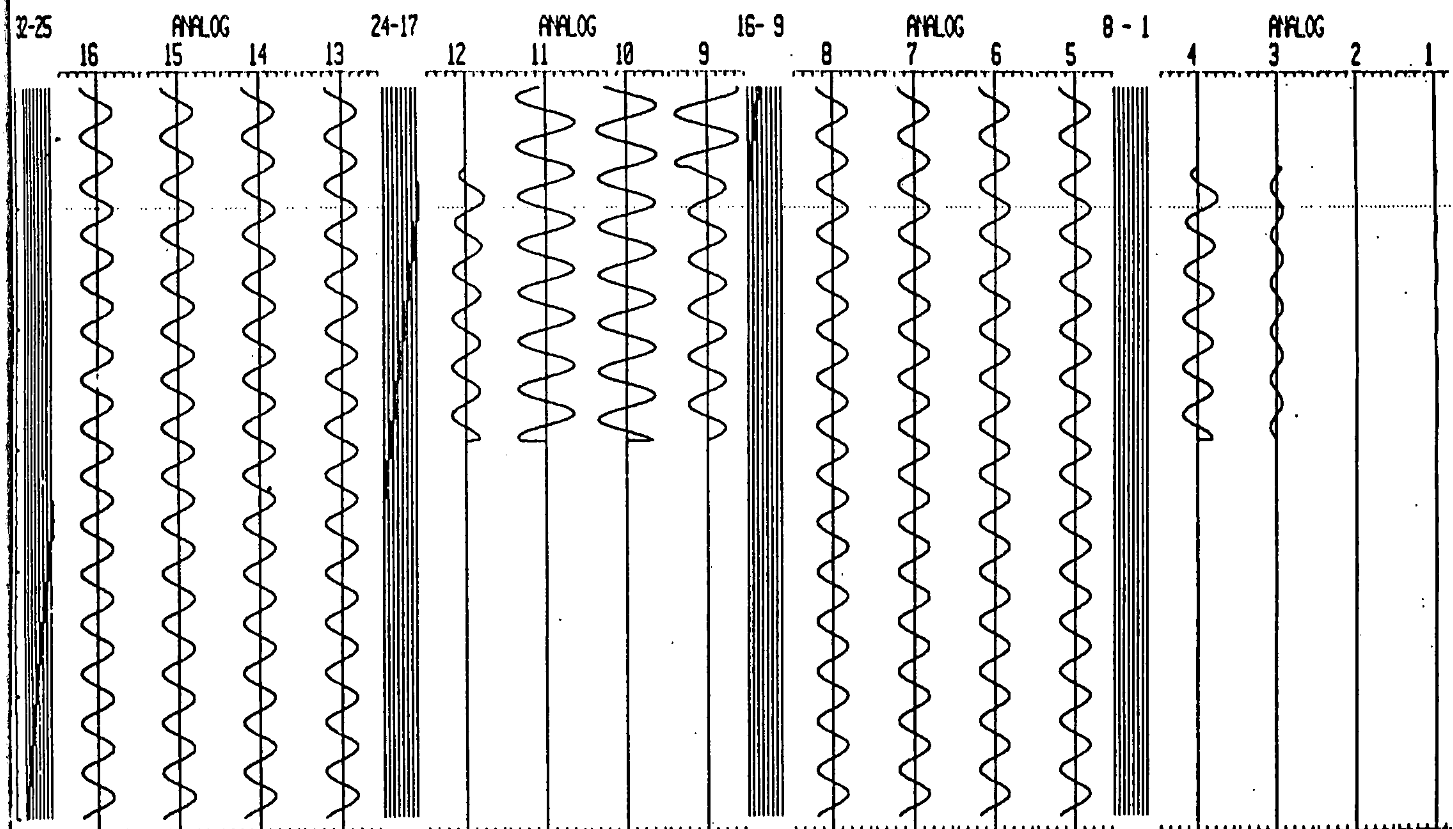


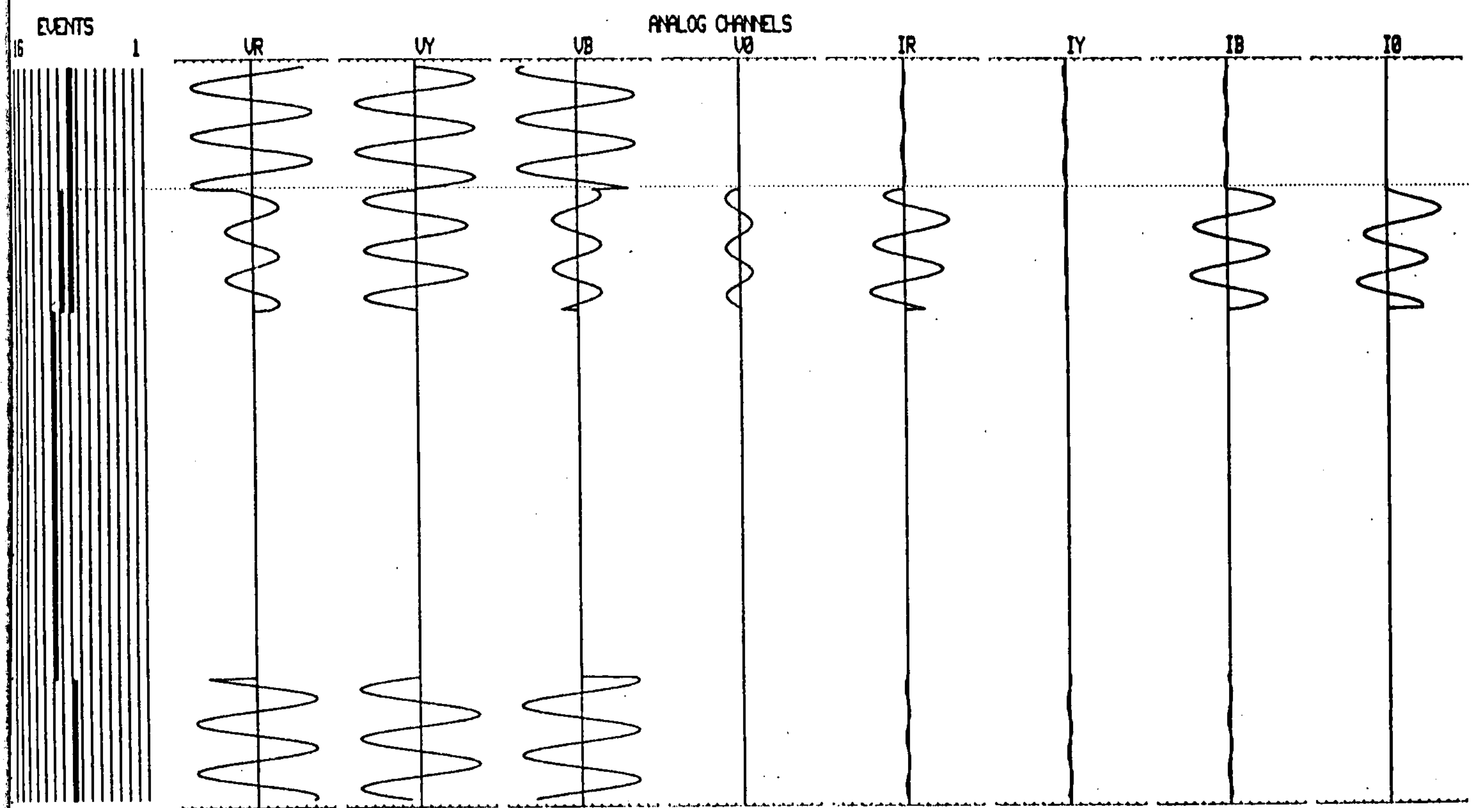
Fig. 2.

(((MICROSTORE DISTURBANCE RECORDER)))

CIRCUITS & SYSTEMS DESIGN

ELECTRICITY COMMISSION OF NEW SOUTH WALES

```
CHINE I.D. :- DEMO PRINTOUT
ULT NO.    :- 0019
ATE        :- 3 JAN 1986
IME        :- 09:24:48.5
ALOG TRIGGER MASK (  8 - 1 ) :- OFF OFF OFF OFF OFF OFF OFF OFF
ENT TRIGGER MASK  ( 16 - 1 ) :- OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF OFF
USE        :- TEST
```




```
RED PHASE FAULT CURRENT DURATION(MILLISECS.)       0050
RED PHASE FAULT CURRENT RMS(KA)                    0004

YELLOW PHASE FAULT CURRENT DURATION(MILLISECS.)    0000
YELLOW PHASE FAULT CURRENT RMS(KA)                 0000

BLUE PHASE FAULT CURRENT DURATION(MILLISECS.)      0050
BLUE PHASE FAULT CURRENT RMS(KA)                   0004

ZERO SEQUENCE FAULT CURRENT DURATION(MILLISECS.)   0050
ZERO SEQUENCE FAULT CURRENT RMS(KA)                0004

DISTANCE TO FAULT CALCULATIONS ARE...   X= 0.195 OHM   R= 0.015 OHM   D= 2.152 KM   CN

EVENT INPUT NUMBER:-  10    CLOSED    09:24:48.500.5
EVENT INPUT NUMBER:-  11    CLOSED    09:24:48.550.5
EVENT INPUT NUMBER:-  10    OPENED    09:24:48.550.5
EVENT INPUT NUMBER:-  09    OPENED    09:24:48.550.5
EVENT INPUT NUMBER:-  11    OPENED    09:24:48.700.5
EVENT INPUT NUMBER:-  09    CLOSED    09:24:48.700.5
```

Fig. 3.

APTS

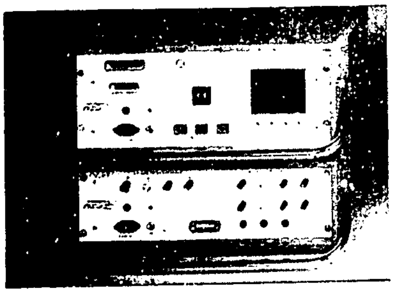


Figure 1
3 Phase Relay Test Set

ORTS

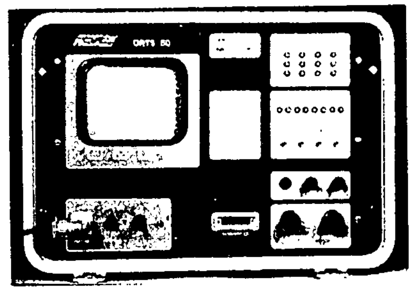


Figure 2
Single Phase Overcurrent Relay Test Set

Figure 3
Reach tests for Distance Delay

```
        R-E ELEMENT

ZONE ONE
   9.66 OHMS AT    75 DEGS.
     NO OP.  AT   255 DEGS.
   8.78 OHMS AT     0 DEGS.
   9.28 OHMS CALCULATED AT 0 DEGS.

ZONE TWO
  19.48 OHMS AT    75 DEGS.
     NO OP.  AT   255 DEGS.
  13.08 OHMS AT     0 DEGS.
  13.68 OHMS CALCULATED AT 0 DEGS.

ZONE THREE
  29.22 OHMS AT    75 DEGS.
   2.44 OHMS AT   255 DEGS.
  12.42 OHMS AT     0 DEGS.
  12.58 OHMS CALCULATED AT 0 DEGS.
```

Figure 4
Polar Diagram for Distance relay

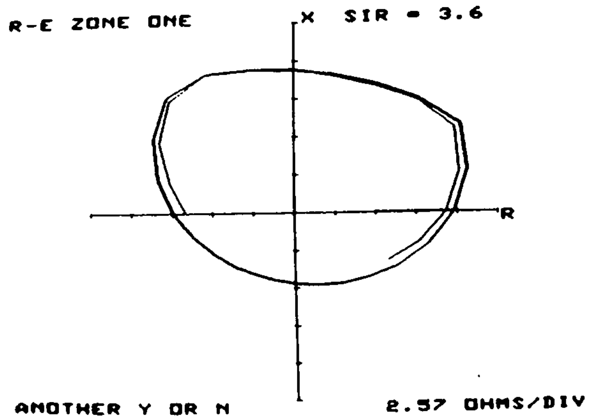


Figure 5
Output for 100% offset current X/R = 50

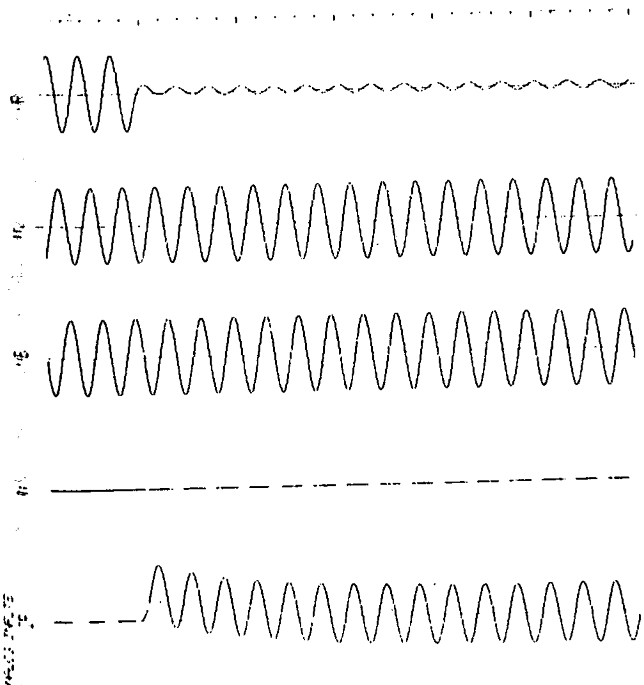
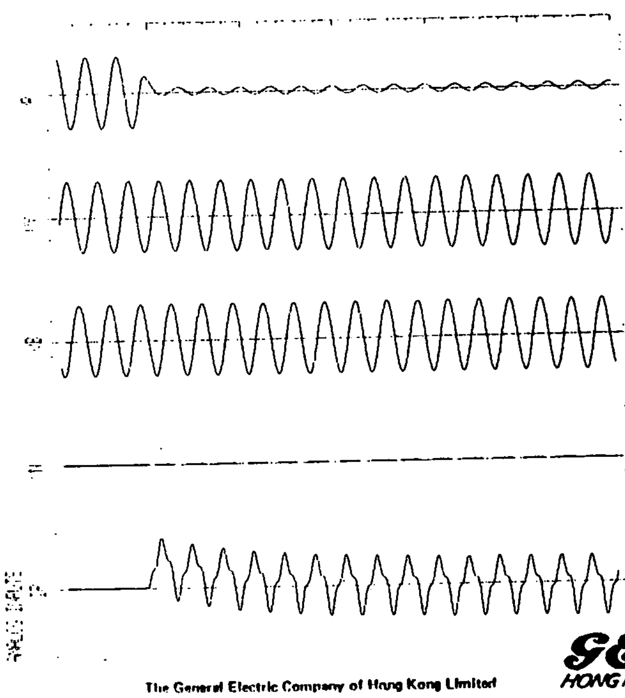


Figure 6
As Figure 5 but with 2nd Harmonic added



Cable fault location ~ a practical guide

The many different methods and types of equipment used for locating cable faults can appear intimidating to some engineers. The use of particular equipment depends on factors such as the type of fault, length of cable, location of cable, cable construction and, very important, funds available for equipment procurement.

by Barry Clegg, Regional Sales Manager — Far East, Biccotest Ltd.

Fully effective fault location on large, complex cable networks can be a complicated and costly process involving many methods and a lot of expensive equipment. This tends to put off many engineers in charge of smaller, less complex cable networks.

However, a great deal of time and money can be saved by the judicious application of modern instruments which need not cost the earth and the use of methods well within the skills and knowledge possessed by most maintenance or contracting engineers.

Whereas a great deal of expertise and experience may be involved in successfully locating the most difficult 10 per cent of faults on, say, a high voltage (h.v.) electricity distribution network, many faults can be found with inexpensive, portable or hand held equipment. The main problem is ignorance — not in a technical sense but in the sense that methods and instruments exist which are not necessarily known about by all cable users. For instance, would the engineer in charge of a flexible cable repair shop in the mining or oil industries know all about the methods used by the electricity authority?

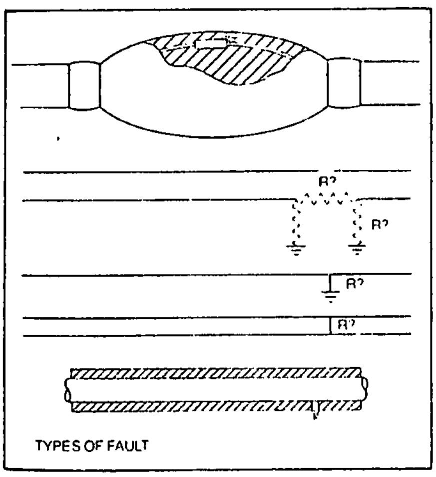


Fig. 1. Types of fault.

Also, the types and lengths of cables used by different authorities dictate methods and costs. A pre-location instrument costing US$1,000, with an accuracy of 0.2 per cent, may give a location on a 15km length of cable one metre deep which requires back up (pin-pointing) with equipment costing US$8,000. However, the pre-location would be all that is required on a 100m length of cable cleated to a factory wall.

Methods and equipment available

With the exception of the introduction over the last 10 years of the Impulse Current Method which locates all types of fault including the "Flashing Fault", (Fig. 1) the basic approach to fault location has not changed for many years.

The methods and equipment necessary are:

Diagnosis	- Ohmmeter - Insulation Tester
Pre-location	- High Voltage Bridge or High Resistance Fault Locator; (Fig. 2) - Pulse echo sets; (Fig. 3) - Impulse Current Equipment.
Fault conditioning (sometimes necessary before pre-location)	- Burn down set
Pin-pointing	- Surge Generator - Audio Frequency set (Fig. 4)
Route Tracing	- Audio Frequency set
Fault confirmation	- Acoustic Detector, Audio Frequency set occasionally
All above funct.	- Combination sets of portable equipment for full fault location capability.
Comp. coverage	— Custom-made modules and test vans for complete mobile flexible fault location capability.

Types of fault

In general faults can be said to be open or short circuits. However, in practice, many conditions can arise, eg a break may not be "Clean" — it may have resistance across it or, more usually, to the sheath or earth. A contact fault may be "hard down" or exhibit hundreds of ohms, kilohms or even megohms (see Fig. 1.). Also, faults occur on one or more of the cores or conductors and all of these variables give rise to the multiplicity of methods and instruments which complicate the issue.

Investigation of fault statistics in the Far East shows marked variations in fault types and causes. Some dense urban areas under constant development show up to 80 per cent due to Third Party Damage and correspondingly low figures for poor quality cable, materials or workmanship.

Other, large areas of mixed urban/rural content show, in some cases, almost all faults due to water ingress resulting from

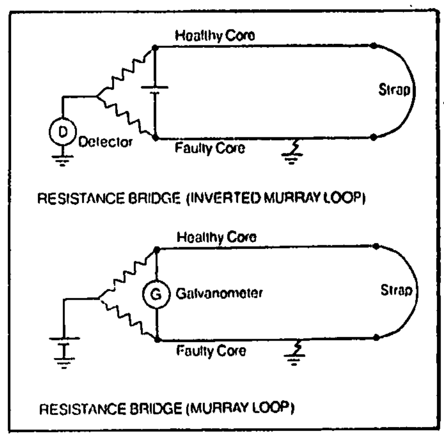


Fig. 2. Murray loop and inverted loop.

bad joining, while others suffer badly from failures due to poor cable quality and have only moderate incidence of Third Party Damage and water ingress. Many faults are high resistance.

Fault location procedure

1. Thorough diagnosis.
2. Accurate Route measurement
3. Trustworthy pre-location (i.e. correct instrument!)

(a) Contact Fault:
Pulse Echo Set if fault resistance suitable. If not, h.v. or high resistance bridge. Impulse Current Set*

(b) Open Circuit:
Pulse Echo Set; Impulse Current Set*

(c) Flashing Fault:
Impulse Current Set

*If available, the Impulse Current Set can be used for open circuit or contact faults of any resistance providing the fault breaks down. On very long circuits over, say 15km, such as long submarine routes, bridges can be used if conditions permit but a method based on h.v. transients such as Impulse Current is the only fully effective approach. Fig. 5 shows a trace obtained during Impulse current tests on the 100kV d.c. English cross-channel link, the fault distance being 39,168m.

4. Pin-pointing:
Surge Generator — occasionally Audio

Frequency sets for low resistance core-to-core faults.

On telecommunications cables, effective fault location depends on each fault/jointing team having a good, low cost, Bridge and Pulse Echo Set. Pin-pointing is rarely possible except when an audio-frequency pick up coil can be applied directly to the cable or when a core or pair in a non-screened cable is in contact with the mass of earth.

Choice of instruments

The main factors governing the choices are:

cable construction (i.e. paper, plastic, cross-linked polyethylene (x.l.p.e.), sheathed, unsheathed)
Cable length
Buried/overground
Prevalent types of fault
Budget

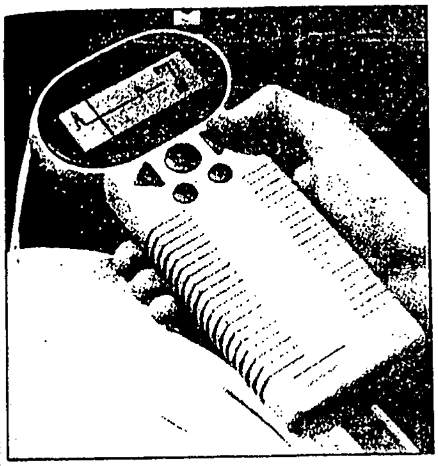


Fig. 3. A T510 hand-held pulse echo set.

If the cable is x.l.p.e. insulated a full set of equipment incorporating Impulse Current Equipment will be required, because it is impossible to burn down faults on this type of cable and pulse echo is therefore not possible for contact faults.

Long cables, say up to 15km present few problems in pre-location but pin-pointing equipment is essential because even a low pre-location error results in a wide search area. Cable location equipment is also necessary.

Short route lengths mean that a rough "one instrument" approach may be successful. For instance, assuming no pre-location is possible, the application of a modern, powerful Surge Generator to just a few hundred metres of cable and the careful patrolling of the route often gives a "spot-on" location within a short time.

Paradoxically, the complete opposite can also be true on relatively short lengths i.e. assuming the only instrument available is a Bridge, the inherent accuracy of which can be within 0.1 or 0.2 per cent, it often enables an accurate location to be made without pin-pointing. In this case, the Bridge should be a modern high resistance fault locator (Fig. 2) so that an accurate reading can be obtained even if the fault resistance is of the order of hundreds of kilohms or even megohms. This avoids the difficulties experienced with older Bridges in trying to effect a balance with very small galvanometer deflections.

On the matter of the minimum amount of essential equipment, it could be said that three units; a High Impedance Fault Locator, a Pulse Echo set and a Shock Wave Generator provide a high percentage of successful locations in most circumstances.

The Pulse Echo set is fully effective for open circuit faults and ultra-modern hand held units are available at very reasonable prices. They will also locate contact faults up to several hundred ohms and are handy for checking the lengths of cables on drums etc. The more refined units have a memory facility for comparing traces.

The following examples illustrate the requirements of a selection of engineers in particular industries and situations: (It is assumed that basic diagnostic instruments and cable tracing equipment is always available).

1. Electricity distribution authority

At central depot:
(a) Fully equipped test van with:
h.v. test facility to 80kV
Impulse Current/Surge Generator
Pulse echo
Acoustic set
Accessories
Generator

Smaller depots:
(b) Portable satellite units comprising:
Impulse Current/Surge Generator
h.v. test to 28kV
Pulse echo
Acoustic set

Extensive cable networks, high fault incidence and the need to restore supplies quickly justify heavy outlay on equipment.

2. Heavy Industry:

Complete portable facility as in 1 (b).

Here cable networks are smaller and fault incidence very low but loss of production can be very costly and a full, mobile capability is justified.

3. Oil Industry:

(Fixed installations and depots)

As 2 above plus on-line fault locators for earth-free medium voltage dc systems.

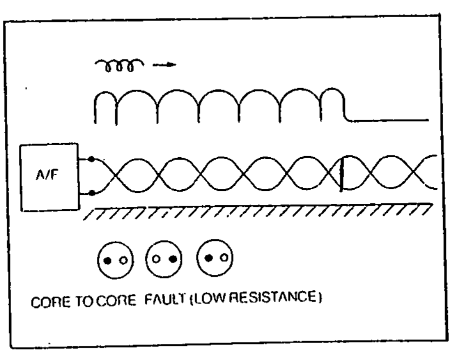


Fig. 4. Audio frequency.

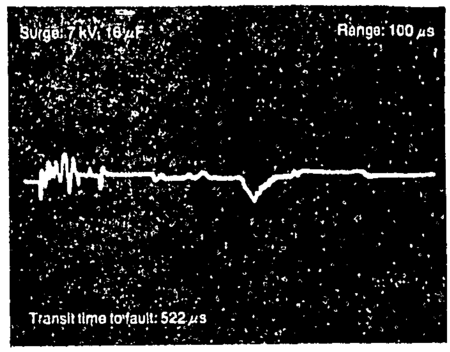


Fig. 5. Oscilloscope trace of the cross-Channel 100kV d.c. cable link between Lydd and Echings.

4. Repair workshop, Oil industry, Mining industry and Cable works*:

Pulse Echo set
High Resistance Bridge
Portable Surge Generator

Because the cables are in coils or on drums, they can be checked for length, breaks and low resistance shorts by a Pulse echo set. Any high-resistance faults are easy to pre-locate with a High Resistance Fault Locator even if no healthy core exists because both ends of the cable are accessible.

*An Impulse Current set can also pre-locate sites of partial discharge in conjunction with discharge testing at cable works.

5. Submarine cable:

Extra high voltage Test Equipment
Impulse Current/Surge Generator
h.v. Bridge/High Resistance Fault Locator

As already stated, long submarine cables cause too much attenuation of the low voltage pulse in a Pulse Echo Set. However, the high voltage surge employed in Impulse Current Testing will travel much further and give "Pulse Echo" type traces for breaks and very low resistance shorts (see Fig. 5) while providing the only means of pre-locating the previously notorious "Flashing Fault".

6. Contracting/Street lighting:

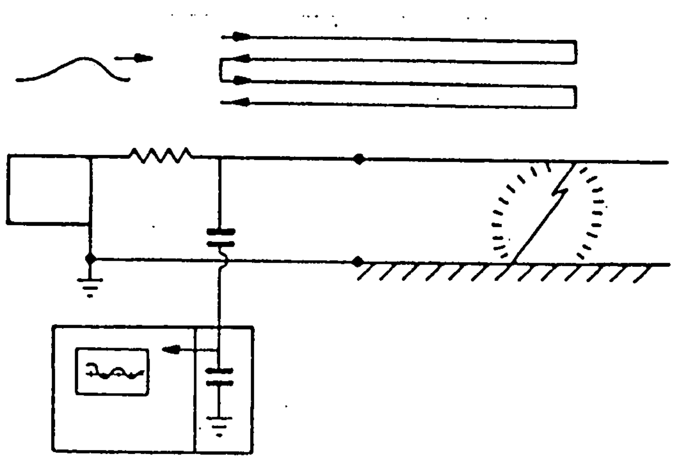
Small hand-held Pulse Echo set
High Resistance Fault Locator
Portable Surge Generator (low voltage)
Portable Burn Down set (low voltage)

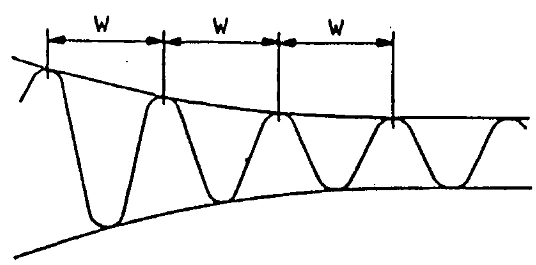
As stated in the text, the relatively short lengths of cable involved often make it possible to dig at a pre-location because the error may be less than one metre and the Surge Generator can be used as a "one-instrument" approach if necessary. Also, on Public Lighting circuits, even when there is no healthy core, the High Resistance Fault Locator can be applied with overground leads.

Finally, although it is very costly to create a capability for finding all cable faults in a very short time, it is hoped that the foregoing will promote some speculation on matching the choice of fault location equipment to the basic requirements of the practical situation leading to more cost effective fault location in all branches of industry.

A short description of the Impulse Current Method of Cable Fault Location

In the past the "Flashing Fault" i.e. a fault which only breaks down at a certain voltage threshold has been easy to pin-point by the Acoustic Method but difficult to pre-locate. Up until about 10 years ago the "Synchronisation" or "Voltage Reflection" Method was in use. This involved the connection of a Surge Generator to the faulty circuit together with a blocking capacitor (capacitor divider). When a fault arcs over, voltage transients are set up which travel from the fault in both directions and are reflected by the end and by an impedance connected at source. The one oscillating between the fault and source produces a low voltage signal in the capacitor divider lower section which is fed to the external input of a pulse echo set (Fig 1).



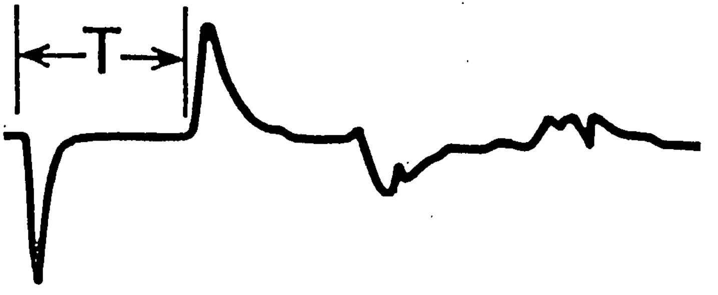


F DIST = 1/2 W

The fault distance is related to the frequency of this transient.

However, the trace is difficult to view and analyse and factors such as the ionisation time of the arc produce errors. The modern Impulse Current Method eliminates these. The method also employs the Surge Generator (necessary in any case for subsequent pin-pointing) but the signal is derived from a simple, safe, linear coupler connected in the earth return of the Surge Generator (Fig 2).

Fig 5:- Open Circuit Fault

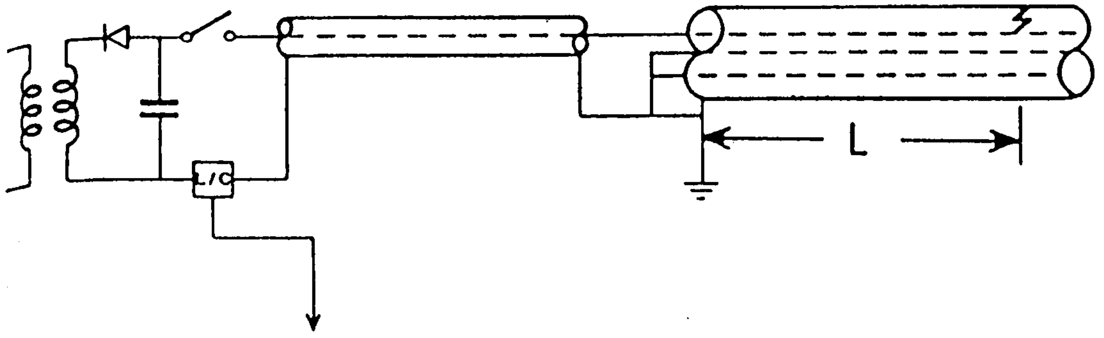


Open Circuit Fault

Fig 6:- Short Circuit Fault

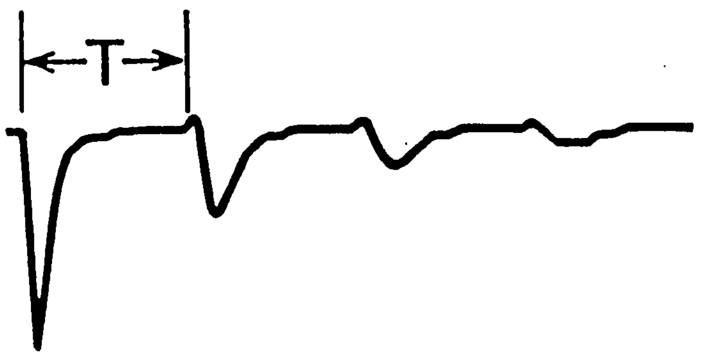
Short Circuit or Low Resistance Fault

It will be noted that the Open and Short Circuit traces are similar to those obtained with the low voltage pulses of a Pulse Echo Set.



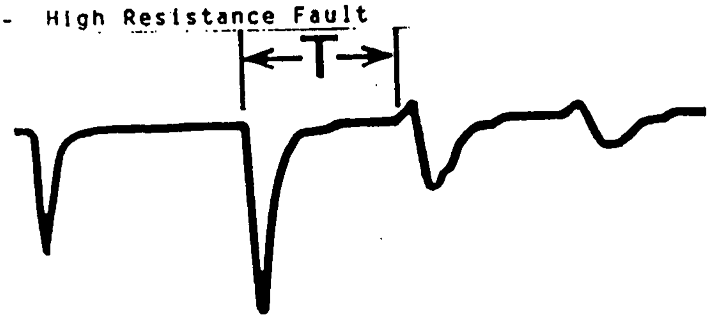
This produces a current signal related to the primary currents caused by the high voltage transient. The oscilloscope displaying the trace thus derived is part of a pre-location unit which also incorporates two digital memories enabling diagnosis to be easily carried out.Typical traces are:-

Fig 3:- Flashing fault



Intermittent or "Flashing" Fault

Fig 4:- High Resistance Fault



Practical Methods of Fault Location For High Voltage Cables Using the Biccotest Impulse Current System

by P. F. Gale, PhD, BTech, CEng, MIEE
Chief Engineer, Biccotest Limited, England

Introduction

Underground high voltage cable networks involve considerable capital investment. No matter how well designed and manufactured the cable and jointing accessories may be, underground systems are exposed to numerous hazards which may lead to their failure. Once a fault occurs on an underground cable system it is essential that it be located and repaired rapidly in order to minimise loss of both revenue and system security.

The BICCOTEST Impulse Current System is designed for the rapid prelocation of high voltage cable faults. In addition to fault prelocation, an effective practical system must also provide for the diagnosis and pinpointing of all types of fault. Such a system is the BICCOTEST 'COMPACT 28' package which provides a cost effective solution to all fault location problems on high voltage power cable systems where portability and simplicity of operation are of prime importance.

Systematic Fault Location

Efficient fault location demands a systematic approach if time and cost are to be kept to a minimum and Table 1 lists the three main stages required. Depending on the type of cable, the fault characteristics and the available test equipment, greater or lesser importance may be attached to one stage rather than another.

Table 1
Three stages of systematic fault location

	Stage	Operation
1.	Diagnose	Confirm existence and determine characteristics of fault.
2.	Prelocate	Test from cable terminals to obtain distance to fault.
3.	Pinpoint	Test in locality indicated by stage 2 to confirm precise location of fault.

Faults can be divided into series or shunt types. Series faults occur where the continuity of one or more of the metallic elements of a cable, either conductors or sheath, is impaired. Usually series faults only become apparent when continuity has been lost completely on at least one conductor to cause an open circuit fault.

Shunt faults occur where the insulation of one or more conductors is damaged. Although shunt faults may involve more than one phase, the most common type of fault is the single phase/earth fault. On screened cables all shunt faults are earth faults. Combined shunt and series faults can also occur. The characteristics of both shunt and series faults can be represented by the equivalent circuit of Fig. 1 which shows the fault resistance, R_f, in parallel with a spark gap, S/G, and a capacitance, C_f. The values of all the elements in the equivalent circuit can vary widely and are completely independent of each other. The breakdown voltage, V_b, of the spark gap is determined by the separation of the two metallic boundaries of the fault which may be bridged by carbonised insulation in a typical shunt fault or air spaced in an open circuit series fault.

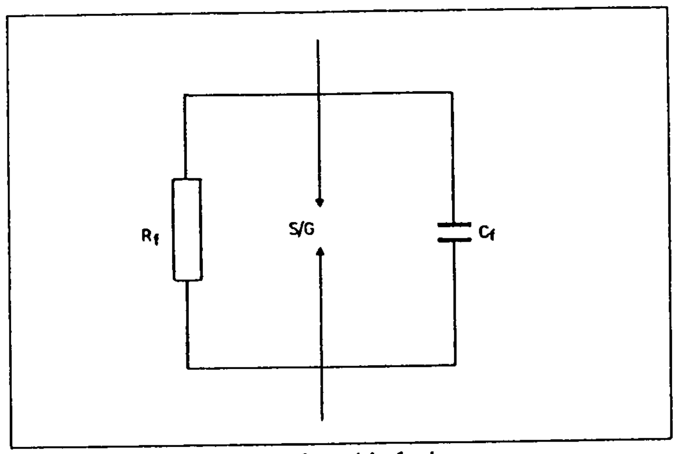


Fig. 1. Equivalent circuit of a cable fault.

The value of the fault resistance is directly related to the degree of carbonisation of the dielectric and the value of the capacitance varies with the amount of moisture present. Table 2 lists the four main types of cable fault.

Table 2
Definition of fault types

Fault Type	Rf	Spark Gap
Series	$\rightarrow \infty$	Breakdown under impulse or d.c.
Low resistance	$< 10Z_o$	Breakdown under impulse if Rf is not too low
High resistance	$> 10Z_o$	Breakdown under impulse
Flashing	$\rightarrow \infty$	Breakdown under impulse or d.c.

Since the Impulse Current Method of prelocation is based on travelling wave principles, the dividing line between low and high resistance faults is taken as a resistance equal to ten times the surge impedance of the cable under test. With surge impedances of high voltage cables being typically in the order of 25 ohms, very few low resistance shunt faults occur. The properties of polymeric insulation usually result in very high values of R_f. Indeed evidence to date suggests that the majority of faults on polymeric cables exhibit a flashing characteristic. It is now generally recognised that conventional methods of fault location, developed over the years for use on traditional paper insulated cable systems, are unsuitable for locating these inherently unstable types of fault.

The BICCOTEST Impulse Current System, by comparison, is ideally suited for use on polymeric cable as the transients produced, particularly by unstable faults, are readily recorded and interpreted to prelocate the fault position.

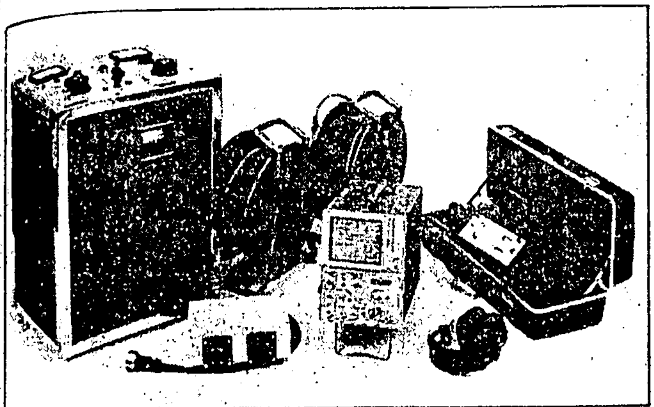


Fig. 2. Compact 28 cable fault location system.

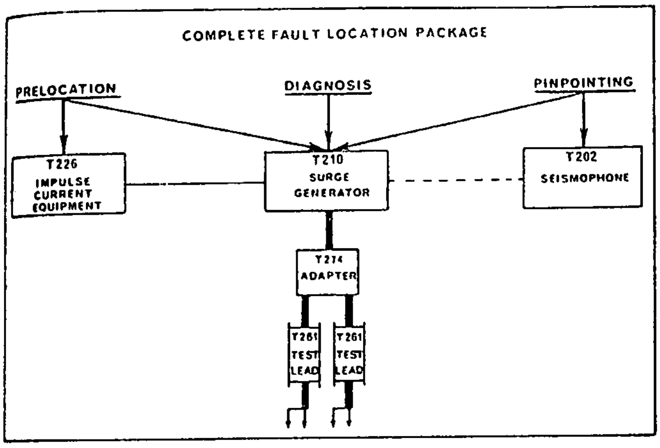


Fig. 3. Compact 28.

Practical System

It may thus be seen that it is necessary to have a system, suitable for all types of faults, which provides for diagnosis, prelocation and pinpointing. The BICCOTEST COMPACT 28 package meets these requirements. The package, shown in Fig. 2, and illustrated diagramatically in Fig. 3, consists of a T210 Surge Generator with a T274 Double Output Adapter and two T261 Test Leads, a T226/DM Impulse Current Equipment, and a T202 Seismophone.

For diagnostic testing of the cable insulation the T210 Surge Generator is operated as a high voltage test set up to 28 kV d.c. For both prelocation and pinpointing, the T210 is operated as a capacitor discharge set with a maximum stored energy of 392 joules in each of its three voltage ranges.

For cable continuity checking, and for prelocation, the T226/DM Impulse Current Equipment is used, deriving its signal from a linear coupler within the T210. The T226/DM is based around a high speed digital transient recorder which is capable of capturing the short duration signals from the linear coupler. Once a signal has been stored in the memory it appears as a steady trace on the oscilloscope display where accurate measurement of the time interval between any two points on the trace can be made using an electronic cursor. An auxiliary memory is incorporated in the T226/DM which is used to store one trace whilst the main memory is recording a second signal. Both traces may then be displayed and their relative positions adjusted for comparison and measurement.

Pinpointing is achieved using the T210 to produce an acoustic signal at the fault which is detected with the T202 Seismophone. To facilitate identification of the acoustic signal in noisy environments, the T202 Seismophone incorporates a magnetic coincidence detection circuit.

Practical Application

A typical fault location on an 11 kV cable is described below with examples of the waveforms obtained. The equipment was connected to the cable under test as shown in Fig. 4, but, initially, for the diagnosis of the fault characteristics, only one of the T261 Test Leads was used.

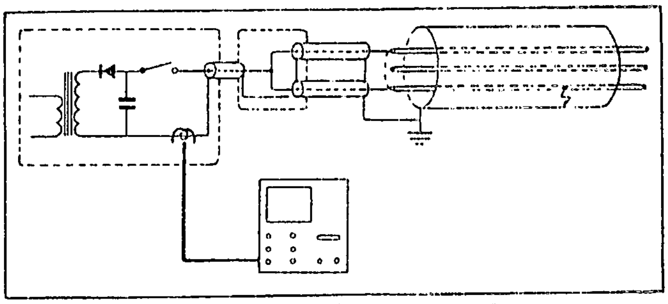


Fig. 4. Equipment and test lead connections for comparison method.

Diagnosis

The three cores of the cable were earthed at the far end and the T210 was used to apply a low voltage impulse to each phase of the cable in turn. Fig. 5a shows the trace obtained on each of the three cores indicating the presence of a short circuit, presumed to be the far end of the cable. When the earth was removed from the far end of the cable, and a similar low voltage impulse was applied to each phase in turn, the trace shown in Fig. 5b was obtained on all three, indicating an open circuit and thereby confirming that the earth had been removed. Thus the continuity of the cable was established.

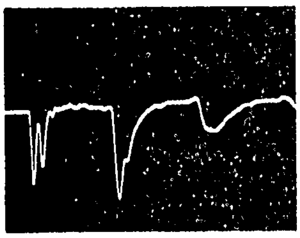


Fig. 5a

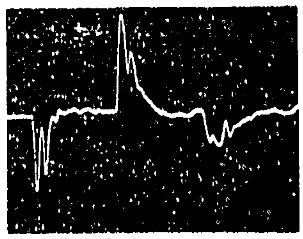


Fig 5b

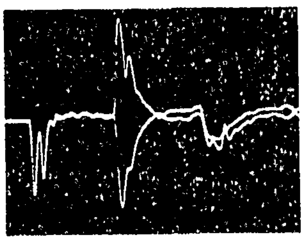


Fig 5c

Fig. 5. Waveform comparison (a) short circuit (b) open circuit (c) both.

Superimposing these two traces, Fig. 5c, allowed the far end of the cable to be identified and an accurate measurement of the total transit time to be determined (5.80 μs). The test lead transit time (0.55 μs) was subtracted to give the cable transit time (5.25 μs).

All three phases of the cable were then voltage tested with the T210 and the following results obtained.

PHASE	kV	mA	Condition
Red	25	0.2	Healthy
Yellow	0.5	40	High Resistance Fault
Blue	11	—	Flashing Fault

Prelocation

Unlike earlier methods of fault location the Impulse Current System is particularly well suited to the location of flashing faults and therefore the Blue phase fault was prelocated first.

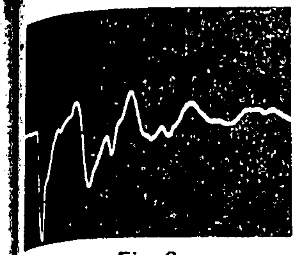


Fig. 6a

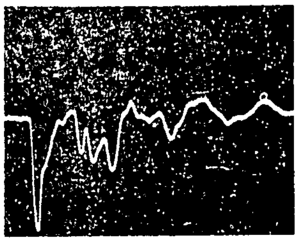


Fig. 6b

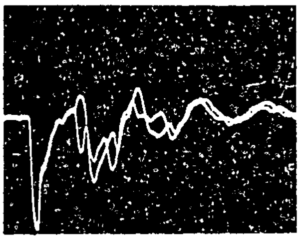


Fig. 6c

Fig. 6. Waveform comparison for flashing fault (a) no loop (b) loop on (c) both.

Prelocation of flashing fault

The equipment was now connected as shown in Fig. 4 with one test lead to the healthy phase (Red) and the other to the faulty phase (Blue). The voltage test mode of the T210 was selected but with the impulse capacitor in circuit. The output voltage was increased gradually until the fault was observed to flash over and the trace of Fig. 6a was obtained. This trace was stored in the auxiliary memory. The T210 was then switched off, the cable discharged, and a high voltage loop connected between the Red and Blue cores at the junction with the test leads. The test voltage was then re-applied and a second flashover obtained, producing the trace shown in Fig. 6b. Superimposing the new trace on the stored trace, so that the initial pulses were aligned, allowed the point of divergence, produced by the loop, to be determined easily, Fig. 6c. Measuring from the initial pulse, the fault breakdown pulse, to the point of divergence gave the transit time to the fault from the loop at the cable termination (3.20 µs). The distance to the fault was then calculated from the following equation.

$$\text{Distance to fault} = \frac{\text{fault transit time}}{\text{cable transit time}} \times \text{cable length}$$

$$\text{i.e. Distance to fault} = \frac{3.20}{5.25} \times 420 = 256 \text{ metres}$$

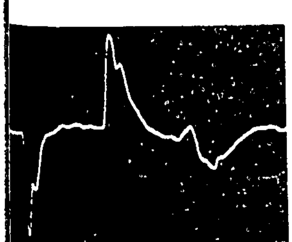


Fig. 7a

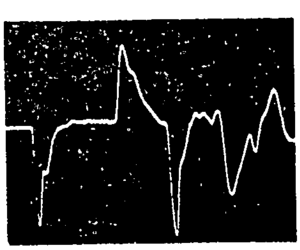


Fig. 7b

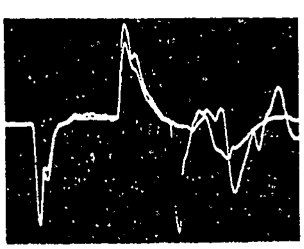


Fig. 7c

Fig. 7. Waveform comparison for high resistance fault (a) no breakdown (b) breakdown (c) both.

Prelocation of high resistance fault

With the equipment connected as in Fig. 4, with one test lead connected to the faulty phase (Yellow), the other still connected to the healthy phase (Red), but with no high voltage loop in circuit, a low voltage impulse was applied and the trace shown in Fig. 7a obtained. This trace was stored in the auxiliary memory. The impulse voltage was progressively increased until a major change was observed in the resulting trace, Fig. 7b. This occurred at approximately 5 kV. The major change, clearly identifiable when the two traces were superimposed, Fig. 7c, appeared as a very sharp negative pulse and was the fault breakdown pulse. This trace was then stored in the auxiliary memory and is shown again in Fig. 8a.

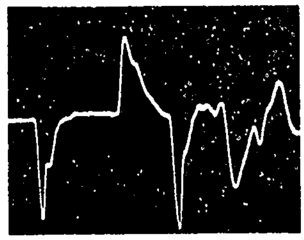


Fig. 8a

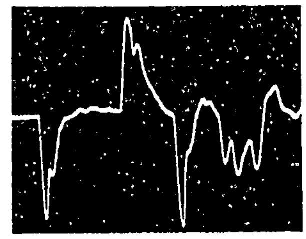


Fig. 8b

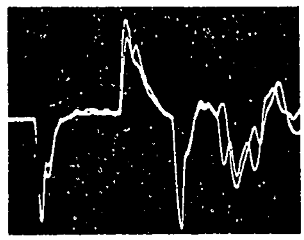


Fig. 8c

Fig. 8. Waveform comparison for high resistance fault (a) no loop (b) loop on (c) both.

After switching off the T210 and discharging the cable the high voltage loop was connected between the Red and Yellow cores. An impulse of 5 kV was then applied and the trace shown in Fig. 8b was obtained. The two traces were superimposed and their alignment adjusted so that their fault breakdown pulses were coincident, Fig. 8c. The transit time to the fault was then determined, as before, by measuring from the fault breakdown pulse to the point of divergence created by the loop (3.20 µs). This result indicated that the high resistance fault was at the same position as the flashing fault.

Pinpointing

The characteristics of the flashing fault in this particular instance were such that the COMPACT 28 could produce a flashover in its impulse mode as well as in its voltage testing mode. Either of the two faulty phases could therefore be used for pinpointing the fault position. The T210 was in fact connected to the Yellow phase and an impulse of 15 kV applied at three second intervals. At the calculated fault position the T202 Seismophone was used to detect the acoustic disturbance created by the impulses and the precise position of the fault confirmed.

Systems for Use at Higher Voltages

Many electricity authorities now prefer to install cable fault location equipment in purpose built test vans so that a greater range and, possibly, more powerful versions of equipment can be provided. Test vans are usually designed for use in both fault location and voltage testing and provide greater comfort and convenience for the operator than is possible with portable equipment. On arrival at the test site the van is energised either from a local low voltage supply or from its own engine-driven generator and high voltage leads are connected to the three phases of the cable to be tested. Once the necessary earthing conditions have been established, these being automatically monitored by equipment in the van, and the safety interlocks completed, all testing can be carried out from within the van. Fig. 9 shows a test van module which has been designed for simple installation into a medium sized van. The module incorporates a 28 kV, 1600 joule surge generator, an 80 kV d.c. test set, an Impulse Current Equipment, high voltage switching and a comprehensive control and monitoring system.

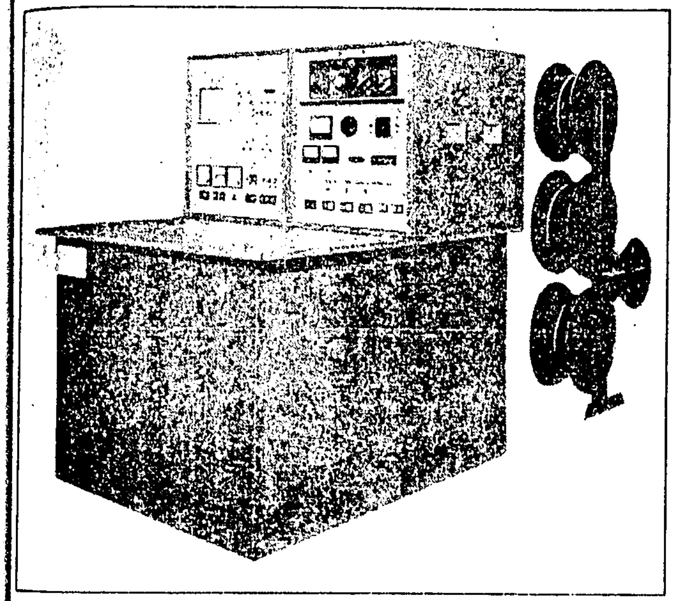


Fig. 9. Module 80 test van package.

Conclusion

The unique BICCOTEST Impulse Current System has eliminated the major problems of fault location on high voltage power cables. Whether the requirement is for an economical and portable system for use on distribution networks, or a powerful installation for transmission system use, the Impulse Current System offers a significant advance in fault location.

Further Reading

1. McAllister, D. "Electric Cables Handbook", Chaps. 29 & 42, Granada Publishing, London, 1982.

2. Gale, P. F. "Cable fault location by the Impulse Current Method", Proc. IEE, Vol. 122, pp 403-408, April 1975.

3. Gale, P. F. "The application of digital electronics to power cable fault location and testing" Electrical World, (Australia), Nov. 1980.

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3. New Developments

Paper No. 6

Busduct – Flexible Rising Mains System

Speakers: Mr. Raymond Lau, Director. Electrical & Electronic Eng. Div., JEC
Mr. Lawrence Ng, Engineer, Electrical & Electronic Eng. Div., JEC

BUSDUCT – A FLEXIBLE RISING MAINS SYSTEM

Introduction

This paper intends to present to the installation contractors, building services consultants and building owners how the busduct system serve them best if it is properly treated.

The busduct system was firstly introduced in the 1920s. It proves to be a versatile, effective means of power distribution method. The system can be classified as:

1. The incomer which is usually short run of high current rating busduct length. It delivers power from the transformer or transit block to the main low voltage switchboard.

2. The main feeder which transmits large lump of power from the main switch- board to other sub-main switchboards or to other vertical busduct risers.

3. Plug-in feeder which has access openings along its entire length to tee off the required power.

Advantages

The standard factory prefabricated busduct and its associated fittings reduce the installation period required. Thus it can provide substantial savings over the conventional cabling methods. Furthermore, nearly all the components can be re-usable. Therefore, the busduct lengths can be removed or re-located at ease and this cannot be achieved with cable installation.

Busduct is best suited to locations where the usual cabling system is impossible to lay due to the limited spaces provided. In cases where there are plenty of tap-off points for diversification of power, cable tappings seem to be more troublesome than the busduct tap-off. Due to these two functions which are satisfactorily fulfilled by busduct, most specifiers favour it as a substitute of cable.

Product design

The busbars must be tin or silver plated over their entire length to prevent the formation of undesirable oxides and maintain a good joint contact. Joints between the individual busduct sections are best coupled together by means of perfect through joint system. A high-strength insulated steel bolt together with the spring washers apply even pressure on the conductors' surfaces. For higher ratings, two or three bolts are used per each 'sandwich' set of conductors.To attain the required bolt torque, some manufacturers employ visual checking bolts to ensure that each joint will be tightened properly, thus overheating at joints and hence damage to the conductors will be eliminated.

Plug-in or tap-off busducts branch-out power through boxes which are either plugged in or bolted on the busduct casing. The positions of the phases and neutral are well separated apart to avoid tracking and yet provide sufficient mechanical strength to sustain short circuit.

The plug-in type branch-out box has long been favoured by building services designer due to its flexibility in terms of its physical location. However, there is a greater tendency to accept tap-off busduct due to the capability of teeing off larger blocks of power. In both of these applications, the busduct contains plug-in or tap-off points so that boxes completed with protective devices can be attached throughout the entire length.

With regard to the plug-in busduct, copper alloy made retainers are attached to each conductor at each plug-in opening so that the fitting operations of the plug-in unit will not hurt the main body of the conductors.

For tap-off busduct, the spacings of tee-off conductors are well apart and insulated to avoid tracking.

Since the conductors are encased in a rigid steel housing, it can withstand the strong electromagnetic forces during a short circuit before the protecting ACB and MCCB trips.

The plug-in units are equipped with protective device such as fuseswitches or MCCBs. These units are polarized to maintain proper phasing. In addition, the units are mechanically interlocked with the busduct housing to prevent installation or removal of units except when the unit is in the 'OFF' position. Moreover, the doors of the units are also interlocked to prevent access when the units are in the 'ON' position and all the line-side parts are provided with safety barriers.

Problems encountered at site

During the past few years, there has been a number of damaged busduct cases reported. In most instances, it was damaged by the ingress of water and especially cement water. In other cases, it was damaged by improper handling.

Most electrical contractors do not treat busduct as a fine and delicate equipment. The installation workers frequently deposit the busduct sections on the ground without proper care. Sometimes, water and silt may seep inside it. On some occassions, water from a burst pipe was splashed on the busducts, causing hazardous explosion and led to a stoppage of electrical supply. Some workers even stroll on top of some busduct sections as a kind of convenient 'walkway'. In doing so they will distort the alignment of the busduct, hence overheating at joints occurs leading to the breakdown of insulating material and short-circuiting.

Prevention and Remedy

To safeguard for all these, the site workers should be taught intuitively on the proper handling and installation of busduct.

When the busducts are delivered to site earlier than required, they have to be stacked in layers with wooden blocks in between each lyaer and off the floor. Most busducts are supplied with both ends covered by steel sheet and plastic sheets but extra protective covering sheets are essential to shield up the whole lot from adverse construction site conditions.

The sections needed in different locations are best distributed with the help of mechanical system such as hoist or trolley. Then damages will be minimized.

Also, weatherproof feeders are strongly recommended when busduct sections run close to or traverse any pipe work. The sealing compound on the casing serves to inhibit water and other foreign material ingress.

Conclusion

Busduct systems have been installed in many major significant projects throughout the world and a lot in Hong Kong. It has proved to be in line with the customer's requirements. Thus, manufacturers are usually responsive at any changes in specifications and are prepared to renovate their products to bring ultimate satisfaction to in aspects of safety and reliability.

Today, busduct systems not only offer easy manageable fittings with superior mechanical and electrical quality, but also simplifies the installation techniques at a reduced cost. Above all, busduct is an indispensible piece of equipment in modern high rise buildings.

Paper No. 7

Quality Control for Nonflammable Power Transformers

Speakers: Mr. Tatsuo Sato, Manager of Quality Assurance Centre
Mr. Atsushi Kudo, Manager of Transformer, Engineering Department B. Mitsubishi Electric Corporation

QUALITY CONTROL FOR NON-FLAMMABLE POWER TRANSFORMER

1. Introduction

As the cities become crowded and complex, the substation equipments in the urban areas are required to be higher voltages and capacities with fire-resisting ability, space saving, environmental harmony and high reliability etc.

For this reason, the necessity of fire-resisting or non-flammable transformers came out.

Class-H dry type transformers and molded transformers are well known as the fire-resisting transformer, but the manufacturing of these transformers are limited up to 33 kV class and 10 MVA.

SF6 gas insulated transformer has been highlighted in these days in cope with high voltage and large capacity transformer.

The SF_6 gas insulated transformer is non-flammable, non-explosive, smaller size and lighter weight, and have been used in Hongkong and Japan for the transformers in buildings, under-ground substations and plants etc., where the fire safety is of primary importance.

The type, manufacturing development, construction and features of gas insulated transformer is mentioned at first, and then the quality control, especially the dust control, moisture control and SF_6 gas seal is reported in this paper.

2. Type of Fire-Resisting Transformer

The fire-proofing manner of transformers may be roughtly classified into three types: the dry transformer using air as the medium of insulation and cooling, the fire-restardant oil transformer filled with fire-retardant insulating oil, and the gas insulated transformer filled with insulating gas.

At the present, four types of fire-resisting transformers are generally used, that is:

(1) Class H dry transformer
(2) Molded transformer
(3) Silicone oil transformer
(4) Gas insulated transformer

Among them the class H dry transformer has the longest history, being used for more than 30 years, and it is most highly evaluated from the viewpoints of both flame resistance and reliability.

The molded transformer was first developed in Europe, and was introduced in Japan in 1975, and it is a relatively new dry transformer, but its demand is increasing because it is excellent in moisture resistance as compared with the class H dry transformer.

The silicone oil transformer is used, outside Japan, in the power receiving and distributing lines, and in Japan it began to be used in 1973 as the vehicle transformers for bullet trains, and it is highly evaluated in flame resistance and reliability.

The gas insulated transformer is a nonflammable transformer of which outer casing is filled with SF_6 gas which is incombustible, nonexplosive, nontoxic, odorless and high in safety. The gas insulated transformer is further divided into the gas-only insulated transformer using SF_6 gas for both insulated and cooling, and the liquid-cooled gas insulated transformer using SF_6 gas for insulation and fluorocarbon solution $C_8F_{16}O$ for cooling.

The present status of fire-resisting transformers in MITSUBISHI is shown in Figure 1, and the characteristics of individual transformers are compared in Table 1.

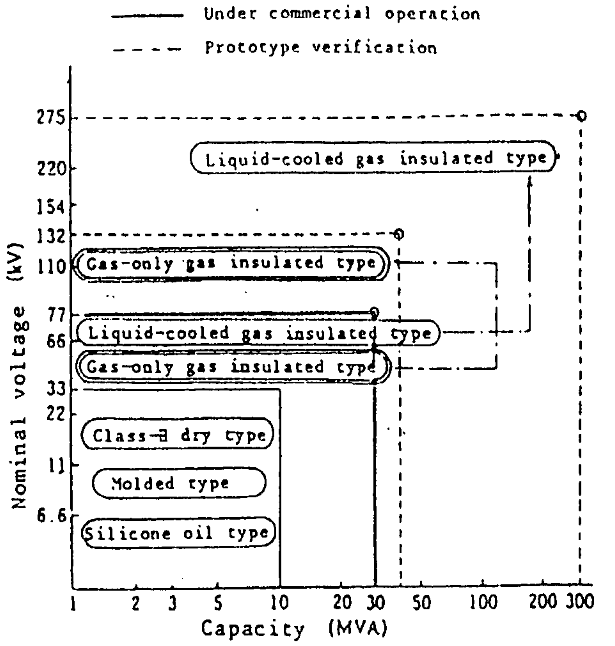


Fig. 1. Present status of fire-resisting transformer

Table 1. Characteristics of individual transformer

Item	Mineral Oil Transformer	Class-H Dry Transformer	Molded Transformer	Silicone Oil Transformer	Gas Insulated Transformer	
					Gas-only type	Liquid cooled type
Insulation Class	A	H	F	A	E , H	E
Material	Mineral Oil Kraft Paper	Air Polyamide film	Air Epoxy resin	Silicone oil Kraft paper	SF6 gas Plastic film etc.	SF6 gas Plastic film etc.
Coolant	Mineral Oil	Air	Air	Silicone oil	SF6 gas	Fluorocarbon Solution
Flammability	Flammable	Flame-retardant	Flame-retardant	Flame-retardant	Nonflammable	Nonflammable
Moisture resistance	Good	Preferable to install in dehydrated condition		Good	Good	Good
Dust resistance	Good	Some kinds of dust may deteriorate the insulation ability		Good	Good	Good
Harmony with environment	Oil outflow	Good	Good	Oil outflow	Good	Good
Noise level	Normal	Higher	Higher	Normal	A little lower	A little lower
Location	Indoor/Outdoor	Indoor	Indoor	Indoor/Outdoor	Indoor/Outdoor	Indoor/Outdoor
Installation	Oil treatment work is necessary	Assembly work with the casings is necessary.		Oil treatment work is necessary	Gas filling	Gas filling
Maintenance interval	2 ~ 3 years	1 year	1 year	2 ~ 3 years	2 ~ 3 years	2 ~ 3 years

3. Manufacturing Development of SF_6 Insulated Transformer

SF_6 (Sulfur Hexafluoride) gas, one of the typical fluoride gas, was recognized as an excellent gaseous insulator in 1930-th, and studied the application to the electrical equipments such as circuit breakers, because of its non-toxic, odoress and chemically stable characteristics.

Getting on this trend, in 1956, General Electric Co. of the United States manufactured SF_6 gas insulated transformer of 69 kV, 2,000 kVA for the first time in the world. Westinghouse Electric Corp. of the United States manufactured, about the same time, a liquid cooled gas insulated transformer of 69 kV, 7,500 kVA. In the United States, gas insulated transformers were manufactured at a maximum voltage of 138 kV and capacity of 40 MVA in the 1960s, but there was no notable advancement thereafter 1).

In Japan, on the other hand, Mitsubishi Electric started researches on SF_6 gas insulation ahead of others, and developed a gas circuit braker in 1965 and a gas insulated vehicle transformer in 1967. In 1967, Toshiba manufactured the gas insulated transformer using a class A insulator as the coil, with 69 kV, 3,000 kVA capacity 2).

But the true development of SF_6 gas insulated transformer was not triggered until the ban on manufacture of PCB filled electric appliances in 1972.

Combining the technology of SF_6 gas insulation and new insulating material technology such as plastics, Mitsubishi Electric turned out a commercial product of gas-only gas insulated transformer of class E insulation with 66 kV, 3,000 kVA in 1979. 3) Afterwards, Mitsubishi Electric have supplied many transformers to the customers, including 11 kV distribution transformers for Hongkong Electric from 1981. (Fig. 2)

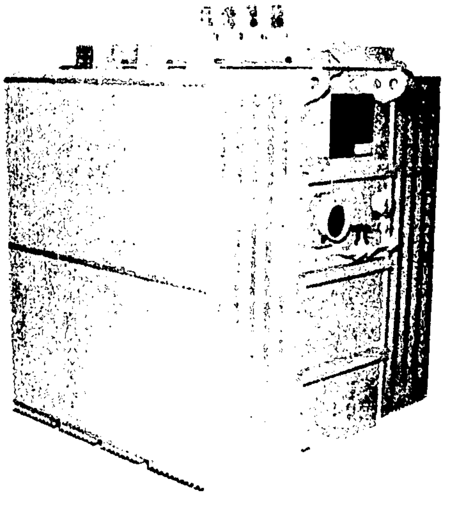


Fig. 2. 3 phase 50Hz 1500kVA GNAN 11/0.38kV

Moreover, using fluorocarbon liquid as cooling medium aiming at application into larger capacity use, a liquid-cooled gas insulated transformer of 77 kV, 20,000 kVA was produced in 1982 also by Mitsubishi Electric. In this transformer, a vacuum switch type gas insulating on-load tap changer was installed for the first time. The maximum capacity of the gas insulated transformers operated at the persent is 77 kV, 30,000 kVA in both gas-only type and liquid-cooled type. The prototype has been verified up to 132 kV, 40,000 kVA for gas-only type, and 275 kV, 30,000 kVA prototype transformer is under verification now. While, 275 kV 300 MVA liquid-cooled prototype of shell type transformer has already been verified 4)

4. Construction and Features

4.1 Construction

The gas insulated transformer generally used at the present is the transformer of enclosed structure, using insulation gas (especially SF_6 gas) as the insulating and cooling medium.

In the large-capacity transformer, aside from SF_6 gas, an incombustible liquid (for example, fluorocarbon $C_8F_{16}O$) is used to enhance the cooling capacity. The former type is called gas-only gas insulated transformer, and the latter is named liquid-cooled gas insulated transformer. Fig. 3 and 4 shows the example of each type.

The gas-only gas insulated transformer, which is the leading faction of gas transformer at present, is further divided into the completely self-cooled type and forced-gas-cooled type using gas blower. They have almost same construction as conventional oil type transformer except for the insulation material and cooling medium employed.

While, the splinkler type is popular for the liquid-cooled type gas insulated transformer in which fluorocarbon solution ($C_8F_{16}O$) is splinked over the coil and core.

The typical construction of completely self cooled distribution transformer is shown in Fig. 5, and those of various cooling type of power transformer is compared in Fig. 6.

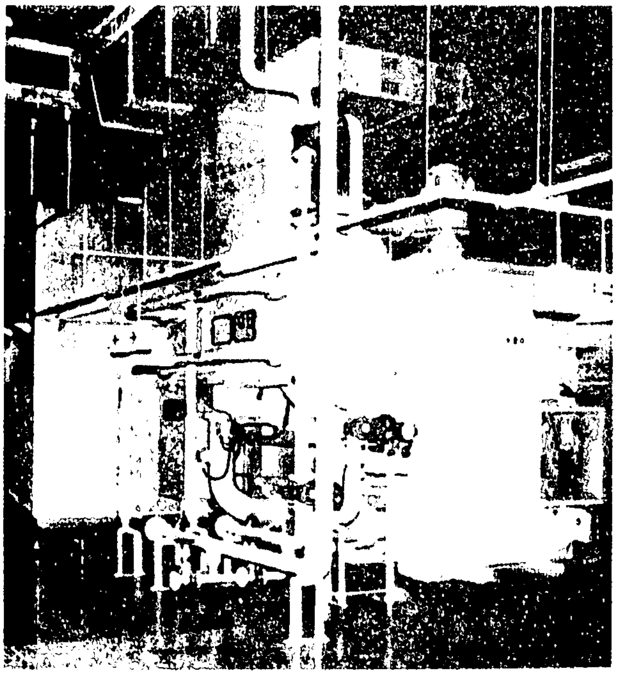


Fig. 3. 66kV, 30000 kVA Gas-only gas insulated transformer
(Forced-gas water-cooled)

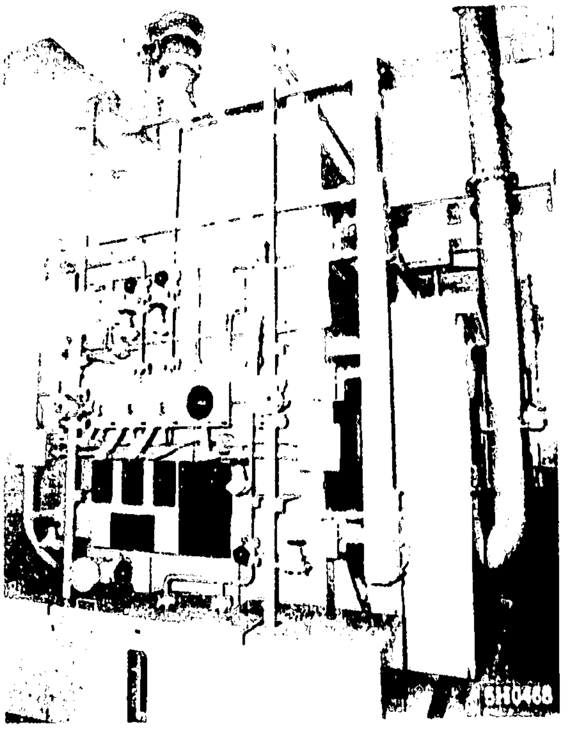


Fig. 4. 77kV, 20000kVA Liquid-cooled gas insulated transformer
(Sprinkler type)

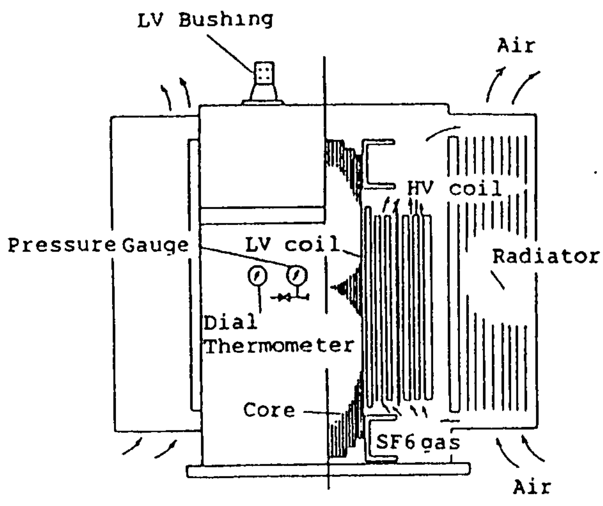


Fig. 5 Typical construction of self-cooled gas insulated transformer
(11 kV class distribution transformer)

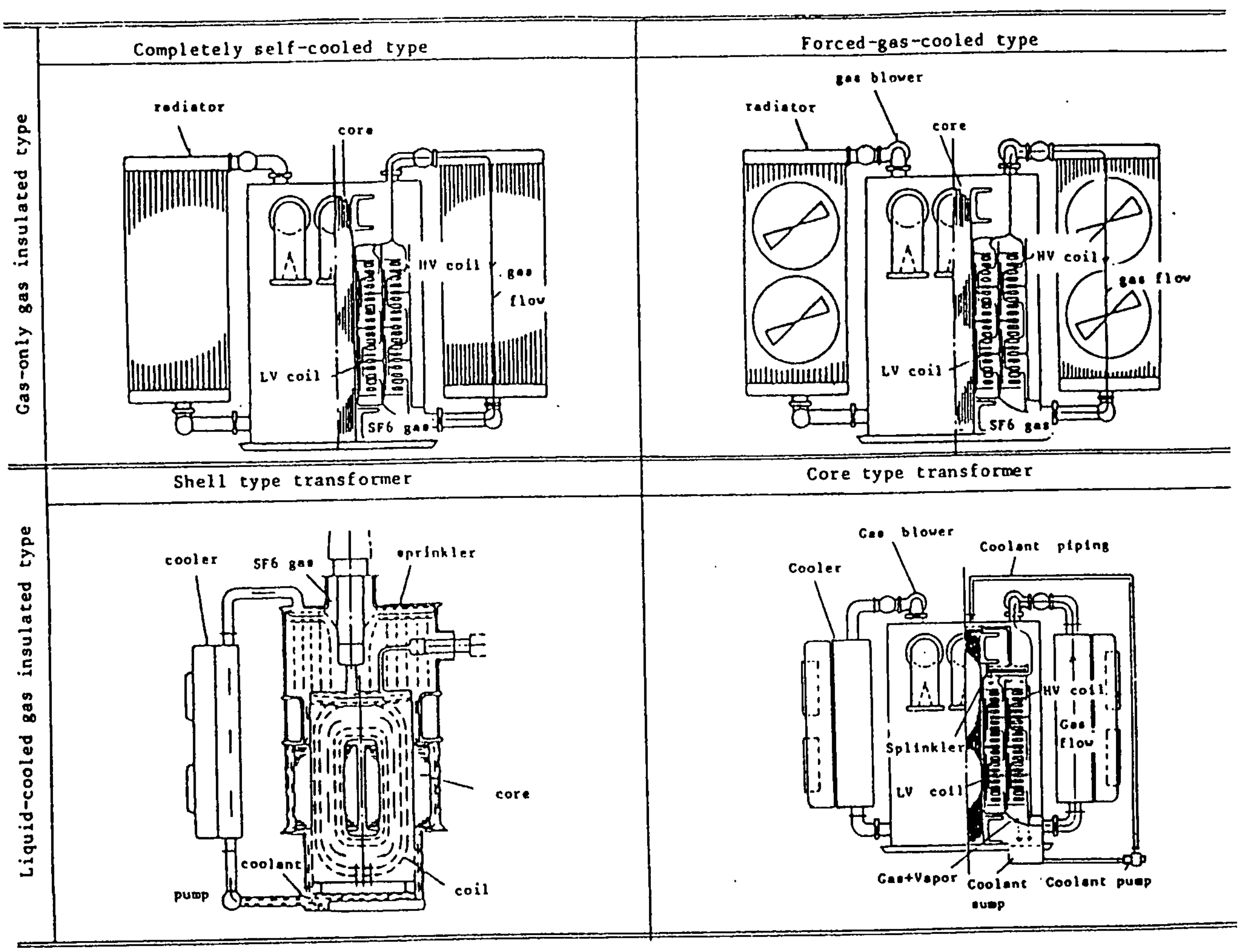


Fig. 6. Construction of gas power transformer

4.2 Features

Features of gas insulated transformer is summarized as follows.

(1) Excellent disaster preventive property:

Because of nonflammability, disaster preventive performance and safety are excellent. Accordingly, the fire extinguishing facilities can be simplified.

(2) Easy maintenance:

Since the iron core and winding are put in the enclosed tank, it is free from effects of moisture or dust, and it is not necessary to check the inside, and the maintenance is facilitated.

(3) Extendability for higher voltage, larger capacity:

Since SF_6 gas is excellent in insulating and cooling characteristics, it is possible to applied in higher voltage and larger capacity uses.

(4) Reduction of space of substation:

By using gas insulated transformer and gas insulated switchgear (GIS), the substation becomes perfectly incombustible, and the space can be greatly saved by directly coupling the transformer with the switchgear. By the reduction of fire fighting facilities and elimination of oil collecting tank, the space of the entire substation can be reduced.

5. Quality Control of Gas Insulated Transformer

As mentioned above, the gas insulated transformer has characteristics of non-flammableness, being used at very important locations and thus required of high reliability. To meet it, we control the gas insulated transformer paying attention to its characteristics on the basis of the quality control of the oil-immersed transformer having been fostered long years. In other words, the basic construction of the gas insulated transformer of gas-only system which is the main stream of the present days is same as the oil-immersed transformer, but what differs is the fact that plastic materials and SF_6 gas are used as insulation ones and SF_6 gas as cooling medium. In this connection, reference is first made to the basis of the quality control and then to the dust control, moisture control, gas seal, and kit system of bolts and nuts and their tightening control which are important control items of the gas insulated transformer.

5.1 Manufacturing standard system

It is very important in terms of quality control to fix its referable standards in doing work and control. In addition to national standards such as JIS, JEC etc., we have made it is rule to arrange manufacturer's standard and do the work and control from design up to installation on the basis of them. The system referred to is shown in Table 2.

Table 2. Manufacturing standard system

Name of Standard		Abbreviation
Rule	Corporate Rule Book of MELCO	- - -
	Rule Book of Ako Works	
Standard	Design Standard Book	S. SS
	Design Manual	
	Design Manual for Transformer, Reactor On-load Tap Changer & Control Panel	STS
	Time Standard	TS
Specification	Product Test Spec.	SSIK
	Process Spec.	SKOS
	Insulation Spec.	SSES
	Finish Spec. (Painting)	NUS
	Finish Spec. (Plating)	SMKS
	Material Spec.	SAI
	Purchasing Spec.	SSAK SKO
	Acceptance Inspection Spec.	SSKE
	Inprocess Inspection Spec.	SMIK
	Tool Spec.	SKOK
	Machine & Equipment Spec.	SSOK
Procedure	QC Process Flow Chart	SKOT
	Work Instruction Sheet	SSYO
	Inspection Instruction Sheet	SKYO
(Drawings)		S

5.2 QC process flow chart

The manufacturing process of the gas insulated transformer is shown in the block diagram of Fig. 7. The QC progress flow chart shown the practical execution of the quality control of the manufacturing process, describing the work of each process in detail and specifying control items, work in charge, standard, record for each process. As an example, the QC process flow chart of coil winding process of Fig. 7 is shown in Fig. 8.

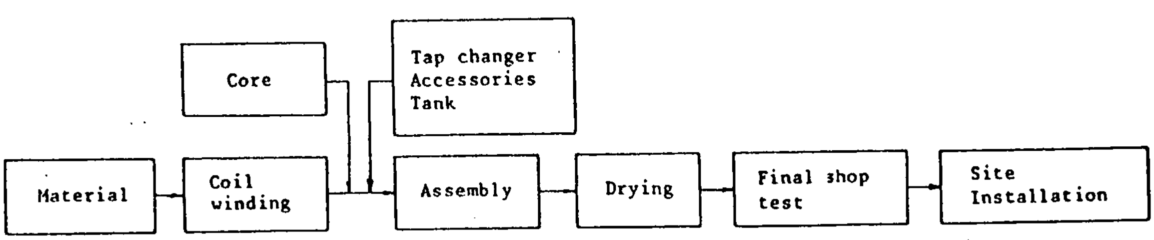


Fig. 7. Manufacturing process schematic drawing

Fig. 8. QC process flow chart

QC FLOW CHART OF COIL WINDING

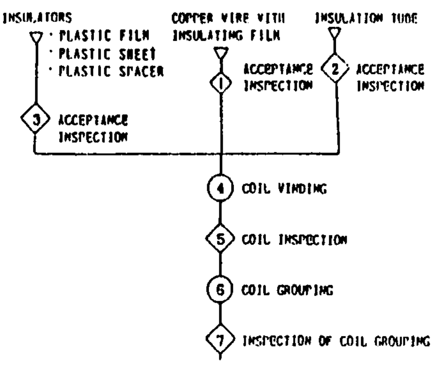


CHART No.	INSPECTION ITEM	SECTION IN CHARGE		STANDARD No.	RECORD
		M.F.R.	Q.A.		
1	APPEARANCE, DIMENSION, NUMBER OF FILM TAPING		O	SKO-30001 SSKE-C0029 SKO-14354	(TEST REPORT)
2	APPEARANCE, DIMENSION		O	DRAWING SSKE-C0029	(TEST REPORT)
3	APPEARANCE, DIMENSION		O	DRAWING SSKE-C0029 SKO-14196	(TEST REPORT)
4	NUMBER OF TURNS, LOCATION OF TAPS DIMENSION, CONSTITUTION OF INSULATOR	O		SSYO-1661C001 ~ 225	MFC-CG1201 MFC-CG1202
5	NUMBER OF TURNS, LOCATION OF TAPS DIMENSION, CONSTITUTION OF INSULATOR		O	SHIR-C166100	MFC-CG1201 MFC-CG1202
6	INSULATOR ASSEMBLY, DIMENSION CONSTRUCTION	O		SSYO-1663C100 ~116	MFC-CG1301
7	INSULATOR ASSEMBLY, DIMENSION CONSTRUCTION		O	SHIR-C166300	MEC-CG1301
8	CORE LOSS, COATING RESISTANCE, DIMENSION, APPEARANCE		O	GSKO-14471 SSKE-S180701	(TEST REPORT)
9	APPEARANCE, DIMENSION, WEIGHT	O		SSYO-1083C616 SHIR-C00754	MFC-CG2301
10	DIMENSION, WELDING, CONSTRUCTION		O	SHIR-C18124	MEC-CG1622

5.3 Important control items

The following items are mentioned about importance of dust, moisture, gas seal and tightening control, which must be paid attention especially in manufacturing control of SF_6 gas insulated transformer.

(1) Dust control

The gas insulated transformer is sensitive to dust and foreign materials. This is a very important subject in control in manufacturing a gas insulated transformer of high voltage and big capacity, and it is necessary to fix and control a control standard in an overall process from maufacturing of materials and parts, assembling, and up to site installation work. Normal dust control items commonly in effect in all manufacturing processes are as follow.

1) Especially an important work shall be done in a clean-booth or air-conditioned room.

2) Dust shall be checked from moving portions such as crane, etc.

3) In inside-tank work, clean dry air shall be blown in to keep the tank at the positive pressure and to prevent dust from entering from the outside.

4) When bringing tools into the tank, their number and appearance shall be confirmed with the check sheet every time they are brought in and out.

5) While parts are kept stored, no rust shall be allowed to generate during transportation and storage of products.

6) In course of assembly work, cleaning by means of cleaner shall be made thoroughly at every work.

In addition, major dust control items in each process are as follows.

Table 3. Major dust control items in each process

Process	Major dust control items
Film winding on copper wire	* Clean booth. * Control of copper wire flaw. * Copper wire's drum shall be covered and stored.
⇩ Coil winding and assembly	* Clean booth. * Iron core and coil shall be assembled within an air-conditioned room.
⇩ Site installation	* Openings shall be covered with vinyl sheets. * Opening time shall be kept to a minimum. * The tank shall be kept at positive pressure by blowing a clean dry air.

(2) Moisture Control

The moisture in the gas insulated transformer will turn dewy on the insulator surface owing to change in the open air temperature and cause insulation to deteriorate. The moisture in gas must be controlled strictly.

1) Control of moisture content

According to SECR (Society of Electrical Collaboration Research in Japan) reported vol. 33 No. 4 MAINTENANCE BASIS OF SF_6 GAS INSULATED EQUIPMENT, it is reported that the deterioration of insulation strength of SF_6 gas insulated equipment due to the moisture in gas is negligible when the dew point is controlled lower than 0°C. We consider the maximum limit of moisture content in SF_6 gas to be approx. 2000 ppm (vol.), as calculated below, which corresponds to the moisture of –5°C dew point taking into account some safety margins. Since the saturated moisture vapour pressure at –5°C dew point is 3.01 mmHg, the maximum limit of moisture content for gas insulated transformer under the pressure of 1.2 kg/cm² · g (20°C) is calculated,

$$V = \frac{Pm\,(-5^\circ C)}{Pg\,(-5^\circ C)} \times 10^6 \quad \text{.........} \quad (1)$$

where,

V = Limit of moisture content in vol. ppm.

Pm (–5°C) = Saturated moisture vapour pressure at –5°C in kg/cm² .abs.

Pg (–5°C) = Total gas pressure at –5°C in kg/cm² .abs.

when,

$$V = \frac{\frac{3.01}{760}}{(1.2 + 1) \times \frac{273 - 5}{273 + 20}} \times 10^6 = 2000 \text{ ppm (vol.)}$$

Meanwhile, it is true that the moisture content in SF_6 gas depends upon the temperature, especially for the equipment which employs a great deal of inside insulation materials such as gas insulated transformer due to absorption or emission of moisture from the insulation materials at lower or higher temperature, respectively. It is ideal to control the moisture for the individual transformer taking into account temperature variation, but we generalize the control basis to be 2000 ppm (vol.) at the room temperature.

2) Moisture absorbant

Moisture absorbant is provided with the transformer inside under manholes to absorb the moisture in the tank and transformer from the outside ambient through the gaskets at the connection flanges etc. during the long term operation. Required quantity of the absorbant is determind in relation to the side of transformer, condition and length of flange connection etc.

3) Check of moisture content

Check of moisture content will be done in factory prior to the transformer shipping and at site in order to confirm the content to be less than 2000 ppm (vol.). After the commencement of the transformer operation, the moisture absorbant which is placed inside the transformer will be expected to avoid increase of moisture afterwards.

(3) Gas seal

Gas seal is the important subject for the gas insulated transformer. Therefore, a welding method, inspection method and sealing method of gaskets of higher reliability than method by means of the oil immersed transformer are adopted.

1) Weld

Method

Transformer tanks are generally welded by the shielded arc welding or semi-automatic are welding. For tanks of gas insulated transformer, an additional Tungsten Inert Gas welding process will be carried out to remove the micro-voids resulting from traditional welding method. The special Tungsten Inert Gas welding method is mainly applied to nuclear equipment and ultra high vacuum vessel.

MELCO consider that with the Tungsten Inert Gas welding, the reliability was improved.

Skill control

From the fact that the quality of the weld depends on the skills of the welder, it is designated as the Qualified work. Since the gas leakage especially of the tank for use of the gas insulated transformer shall not be allowed to take place by all mean, we have made it a rule to make welding of high reliability by a welder who was designated after judging his carrier, efficiency of skills etc. from among those who passed the JIS technical examination.

2) Leak test method

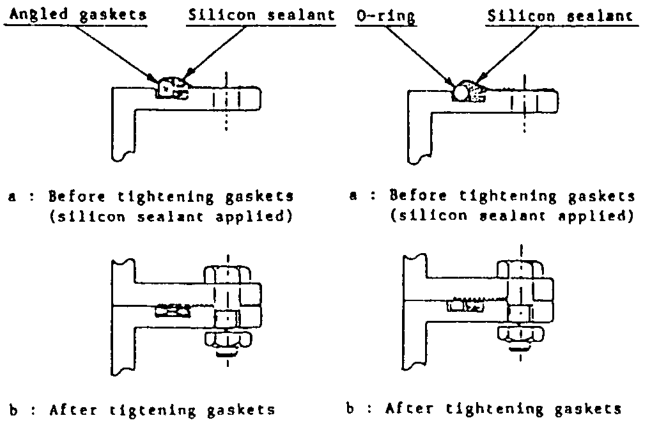
To make sure of no gas leakage from welding and gaskets parts, the following leak test is carried out to manufacture a gas insulated transformer of high reliability. As shown below, it is confirmed that no leakage is observed at a pressure above the gas pressure at the time the operation took place in the four processes of components, tank manufacture, assembled and completed transformer and after site installation.

Table 4. Leak test of gas insulated transformer

Process (Object)	Sealed gas	Inspection method
1. Components (Radiator valve, Blower, SP relay & etc.)	SF_6 gas	After sealed with SF_6 gas. the components shall be cover with a vinyl sheet, and gas leakage shall be measured with an SF_6 gas detector.
2. Tank manufacture (Transformer tank)	Fron gas	Welding zones shall be checked by tracing for the presence of gas leakage by means of a halogen detector.
3. Assembly of transformer (Assembled transformer)	SF_6 gas	Connections with gaskets shall be covered with a vinyl sheet and subjected to gas leakage measurement by means of an SF_6 gas.
4. Site installation (Assembled transformer)	SF_6 gas	Same as above.

3) Seal of gaskets construction

In selecting gaskets material, it must excel in durability and high-low temperature characteristics and allow the minimum water permeability. Our company is in use of nitrile-made O-ring and angled gaskets which satisfy the above mentioned condition. To enhance the reliability for gas leakage in addition, silicon sealant is applied to gaskets grooves and flange surface (atmosphere side) as shown in the following.



(4) Kit system and tightening control of bolts and nuts

Leaving bolts, negligence in bolting, looseness in tightening bolts at the inside of gas insulated transformer, such non-conformity will lead to a big accident, it must accordingly be prevented by all means. With this, our company is doing thorough control of kit system and tightening, as follows.

1) Necessary number of bolts and nuts shall be arranged at other location in accordance with the drawing. Only such parts as collected in the parts box shall be used.

2) Bolting shall be made with a torque wrench and confirmed by double checks by the worker and inspector.

3) Indication of confirmation of the tightening shall be marked on the bolt and entered in the check sheet.

6. Conclusion

In connection with the gas insulated transformer as stated so far, we have made enough verification for its practical use since we started its development in 1963. With regard to the quality control in way of manufacturing too, we control the gas insulated transformer with its important control items fixed on the basis of our experience in manufacturing various transformer having been fostered long years. As a fruit of our efforts, since it was began to be adopted regularly in 1979, we made lots of actual records of more than 1500 units. With the latest techniques and quality control introduced on the basis of the said actual records, we are under additional development of a gas-only gas insulated transformer of high voltage and big capacity to realize practical use of a 275 kV transformer in 1989. MELCO will supply 275kV 300MVA liquid-cooled gas power transformer to some Electric Power Co of Japan in 1990. As a result, the gas insulated transformer which is non-flammable will come to be available over all voltage area up to 275 kV which is used in big cities and it is certain that it will do a great help to prevent disasters in cities.

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Paper No. 8

Flexible Cable Rising Mains

Speaker: Mr. W. P. Po, Manager, Electrical Engineering Dept. Swire Engineerig Services Ltd.

CONTENT

Introduction

The methods of electricity distribution are numerous. The design engineers can have many choices such as power cables, busbar trunkings etc to suit their applications.

Due to the complexity of electrical distribution in modern buildings, most of the engineers are looking for a distribution system to cater the reliable and durable purposes. Meanwhile, the system has to be cost effective and labour saving. Among the L.V. cable distribution systems, there is a system called Branch Cable System which is originally developed by most of the Japanese manufacturers, is getting propular in Hong Kong.

It is considered to be viable to apply to the distribution circuit with many points of tap off, such as riser system and the distribution systems required a lot of branch circuits.

The Construction

It possess a very distinct feature thtat this Branch Cable System is made up by the single core cable with either PVC or XLPE insulation and PVC sheathed. Generally, single core or single core twisted type cables are used as vertical trunk cables and single core cables as branch cables: Fig 1 & 2 shows the typical construction of the system. Both the trunk cable and branch cable comply the IEC502 standard.

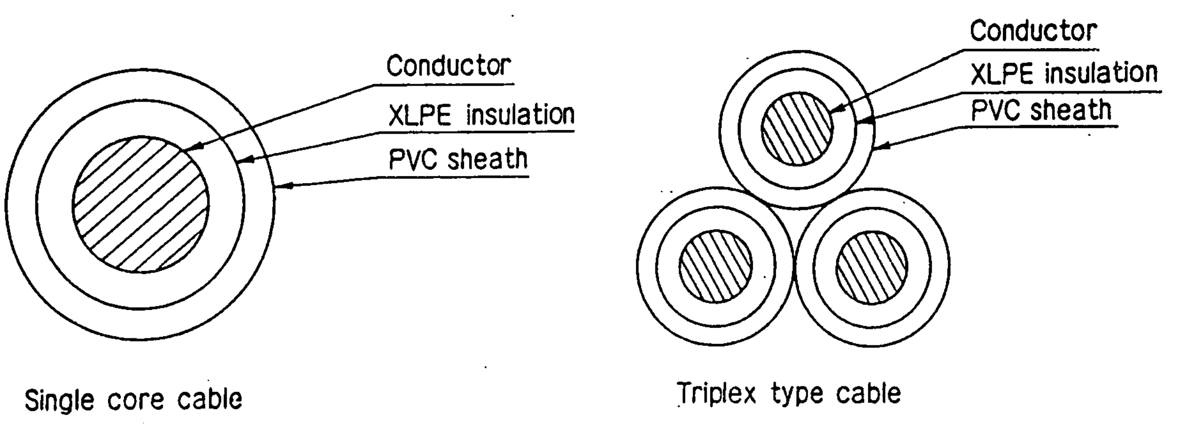

Fig.1 Construction

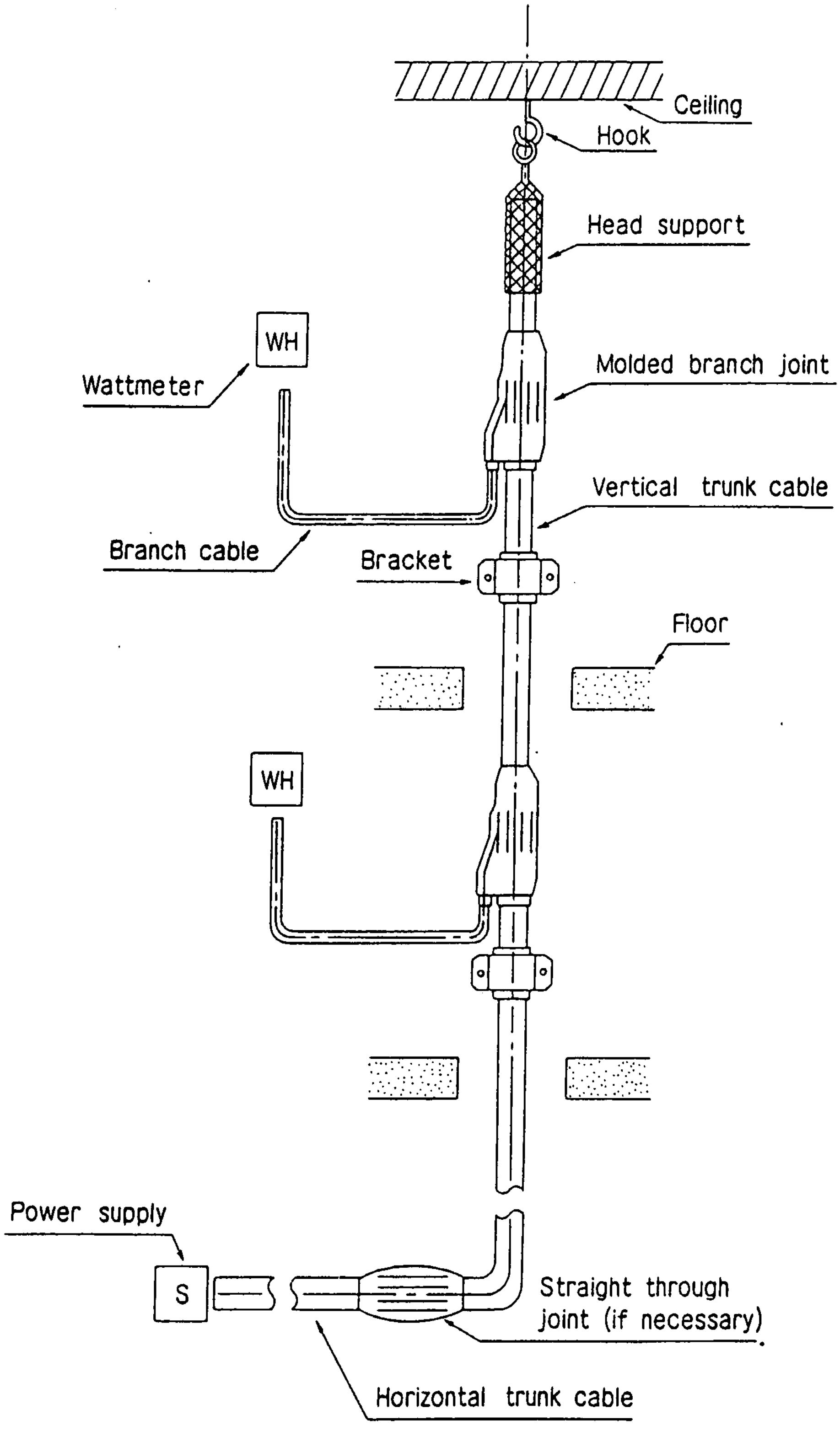

Fig. 2 Outline of Branch Cable System

600/1000V single core XLPE/PVC power cable

IEC Standard Pub. 502

Conductor			Thickness of insulation	Thickness of sheath	Approx. overall diameter	Approx. weight	AC test voltage	Max. conductor resistance (20℃)	Current rating	Voltage drop X10^-3
Nominal sectional area mm²	No. & dia. of wire or shape No/mm	Diameter mm	mm	mm	mm	kg/km	KV/5min	Ω/km	A	V/A·m
6	7/1.04	3.12	0.7	1.4	8.0	105	3.5	3.08	61	3.3
10		3.7	0.7	1.4	9.0	150	3.5	1.83	85	2.0
16		4.7	0.7	1.4	9.5	215	3.5	1.15	113	1.3
25		5.9	0.9	1.4	11.5	310	3.5	0.727	150	0.84
35		7.0	0.9	1.4	12.0	410	3.5	0.524	181	0.63
50		8.5	1.0	1.4	14.0	570	3.5	0.387	265	0.49
70		10.1	1.1	1.4	16.0	770	3.5	0.268	290	0.36
95		11.7	1.1	1.5	18.0	1,030	3.5	0.193	347	0.29
120	Compact round stranded	13.2	1.2	1.5	20	1,280	3.5	0.153	410	0.24
150		14.7	1.4	1.6	22	1,590	3.5	0.124	470	0.21
185		16.4	1.6	1.6	24	1,950	3.5	0.0991	530	0.19
240		18.6	1.7	1.7	27	2,490	3.5	0.0754	640	0.16
300		20.8	1.8	1.8	30	3,140	3.5	0.0601	725	0.15
400		24.1	2.0	1.9	34	4,140	3.5	0.0470	845	0.13
500		26.9	2.2	2.0	37	5,140	3.5	0.0366	980	0.12
630		30.2	2.4	2.2	41	6,440	3.5	0.0283	1,150	0.11

Application And Advantage

1. Total expenses of construction work, including personnel and material expenses, are considerably decreased because of saved manpower at the site.

2. Most of the site work is carried out at the factory. It saves time and labour at the site.

3. Branch and head-support work that affect the electrical and physical properties of the system are carried out at the factory under quality control and a well-arranged working nvironment. Moreover, the factory undergoes all the necessary inspections before shipment. Then, it will ensure no mistake being made during the joint making process.

4. This cable system is always wound around a drum and arranged for easy installation at the site. Therefore, the management work at the site such as arrangement of installation schedule, procurement and storage of necessary materials, etc., is reduced.

5. The shaft is used only for pulling up the whole cable system, therefore the required space is reduced.

6. Branch sections are injection molded with black PVC after conductor compression jointing. PVC injection mold assures water-tightness and excellent electrical and physical characteristics.

   Taping work at the construction site can't assure these characteristics.

   The branch joints and the head support of the cables are so airtight and waterproof that the cable system applicable to a humid or wet area.

7. Each core is inked with straight colour line mark on the sheath or the colour of the

sheath which gives the exact phase indentification along the cable.

8. Low impedance flat pre-branched cable.

   Flat separate-conductor (multi-conductor) cable construction reduces line impedance to the minimum. Suitable for large buildings.

4. Installation

Paper No. 9

On Site Quality Control

Speakers: Mr. T. L. Chau, Manager, Electrical Contracting Division, China Engineers Ltd.
Ms. S. T. Chan, General Manager, Trident Engineering Co. Ltd.

ON SITE QUALITY CONTROL

There is generally no explicit terms in defining the quality systems to be employed in the conditions of contract and people quite often relate "quality" to "workmanship" which is a ball in the court of the Contractors.

It is not true.

A quality job means the right material being installed at the right place, at the right timing, with the right method and tooling by the right personnel plus adequate assurance tests in parallel all through with accurate documentation.

To achieve the above, it needs joint effort from various parties and we shall look at the criteria of a quality job individually:

1. The Right Material

A. Materials selected by Consultants/Architect/Client

The choice of the type of material normally rests with the Consultants and the Architects or Clients, the Contractor is to ensure the right type of materials are ordered and are manufactured to the specified standard. How to achieve this is outside the scope of this paper, but in most of the cases, it is not practical to monitor the manufacturing process of the supplier. Care has to be taken at material-on-site stage.

The following steps need to be taken:

a. Before material arrival, arrange a suitable storage space with access problem all resolved.

b. Decide a suitable transportation method.

c. When material arrived, check the model no. against the specified ones and then check conditions of casing, record any damage found.

d. Check quantity and update site stock level record.

e. Identify locations where the particular material is to be used.

f. Agree sequence and/or arrangement with supplier on open casing inspection and warranty validity for open-cased material.

g. Mark out and put aside separately items not up to standard and return the same to the supplier. Care should be taken that the sub-standard items may not be used inadvertently.

h. Arrange distribution of inspected material for installation.

i. Update site stock level after material distribution.

j. Arrange replacement/filling up substandard items and undersupply items, repeat process from a.

The above process is particularly important when material are freed issued from the Client.

B. Materials selected by Contractor

The material that is normally decided by the Contractor are the mounting method.

The guidelines of material selection is normally specified, the following points however is to be noted in particular:

a. Strength and Safety consideration, the dynamic load that may arise during installation has to be taken into account.

b. Structural tolerance, suitable flexibility in mounting bracket design may eliminate a lot laborious work.

Other materials that may usually skip attention are the terminating accessories. There is no simple way out except careful planning. To highlight the following points at time of order for switch boards/switch gears can eliminate a lot of trouble that may arise in future:

No., type, size of cables entering the equipment.

Identify top/bottom entry or other specific requirements.

Identify bolt size for cable termination.

Identify minimum clearance for cable bending.

Identify busbar extension that may be needed for cable termination.

C. Busbars

Busbar is an item worth special attention. The installation of busbar needs very precise dimensioning. For this reason it is always recommended that dimensions be taken on physical site, and where not practical, dimensions MUST be taken from structural drawings and cross checked with site dimension later. For economic transportation reasons, busbars are normally not grouped logically for installation in each container, it is therefore necessary to sort out the busbars according to their run before erection.

2. The Right Place & The Right Timing

The installation of the material at the right place and the right timing needs a lot of effort in coordination. The subject of coordination has been dealt with in great depth in various occasions. As Contractors are concerned, the ideal case is to have coordination arranged in the following steps:

Preliminary coordination of physical location.

Design of support system and decide installation method.

Detail coordination of physical location and sequence of work.

After the coordination of the work, it is best to arrange a mock up to be erected and adjusted where necessary.

The above is an ideal situation and very often this cannot be achieved due to the change of design after detail coordination. Theoretically the whole process of coordination need to be redone. Sometimes the designer has considered the effect of the design changes. The Contractors are to keep a clear record of all the changes issued and to ensure that work is carried out according to the latest revision. With the development of the microcomputers, the variation work involved can be sorted out easily before actual work is carried out. After the information is sorted out, it is necessary to ensure the correct information is passed to the workers, and such is made through the supervisory staff and inspected by client's representative at regular interval.

3. The Right Method and Tooling

The installation instruction normally comes together with the equipment casing, or a separate manual is available in case of complicate equipments. Special tooling may be required to complete the installation, such tooling will be highlighted in the installation manual, it is important that the right tooling be used when performing the installation.

Very often the material are imported and are delivered to site directly. It is therefore very important that the site team really takes the care to read and follow the installation manual. Practically it is not easy and the introduction of "installation method statement" prepared at project engineer level may be a solution. This will increase the normal work-load of the project engineer and finally increase the cost of the whole installation. The Developer has to decide between a better quality system and an slightly economical installation.

The right level of supervision is required to ensure the correct method is being employed, and the normal channel is

Supervisor
|
Foremen
|
Workers

It is important that the planned method is being understood by the actual workers and any actual problem can be reflected back to the personnel in charge. Spot check and surprise check are the usual means to ensure workmanship.

As a broad rule, to keep the quality of work better, the on-site modification of material should be kept to a minimum and that the better the tooling, the better the quality.

4. The Right Personnel

The system used in Hong Kong is sub-contracting. The actual team doing the installation is the sub-contractor. This is not contravening with the British Standard as work is normally divided into different trades to those workers who has experience on similar installation and preference of course will be given to those showing better performance.

The problem here being firstly, the tender system in Hong Kong normally does not allow for merits from past reference, that is, the one with the lowest bid will normally get the job. This concept will undoubtedly be passed to the sub-contractors, the one which shows best performance in the past may not necessarily be the cheapest offer, and a compromise will have to be made between confidence from past performance and economical factors.

Secondly, especially with the current labour shortage, even with the best sub-contractor one is having from his past experience for that particular type of work, the actual workers on site may be changing from time to time. How well a job can be performed will depend on the team leader of the sub-contractor and what is available at the market.

Thirdly, the lumpsum tender system in Hong Kong also post great difficulties in getting the right people to work during labour shortage periods. This is because that a medium to large size contract will normally last for 3 to 4 years, it is quite unimaginable how someone tendering 3 years ago will know the extent of labour shortage we are facing now. As the Contractors are not compensated for the labour escalation, the sub-contractors will not be compensated accordingly. This will lead to either less skillful staff be employed or the complete walkaway from site by the sub-contractor. Both cases will be disastrous to the job performance and the latter case will also lead to complicated contractual chaos which will be out of the scope of this paper.

Lastly, there is a new format of contract introducing to the existing contract system, both by the Government and the private sectors. The conditions stated in the new format are yet not well mature. Such conditions will bring difficulties to the project co-ordination and also to cost the project more.

The writers of this paper are not able to present a solution to these problems. The introduction of registration and grading of electricians may be the first step to solve part of the problem and a final solution may involve a change in tendering concept.

5. Quality Assurance Testing

After all the above criteria have been met, the installation must go through a series of quality assurance tests, such test may not be carried out at the final stage, and quite often it is necessary to carry out test at very short interval. A typical example will be busbar insulation test. To identify a piece of low-insulation busbar after the complete run has been installed is a disaster. This is especially so for high amperage busbar for high rise building. The testing of busbars section by section after its sectional completion can save a lot of trouble in future.

The following table lists out the normal tests to be carried out on site for quality assurance of various activities:

Activities	**Normal Quality Assurance Test**
Conduit Installation	Earth continuity test
Cable Installation	Insulation test
Switchgear, busbar and distribution Board Installation	Insulation, earthing and phase sequence tests
L.V. switchboard	Tests as recommended by manufacturer
H.V. switchgear and transformer	Tests as recommended by manufacturer
Electronic devices and circuits	Tests as recommended by manufacturer
Earthing system	Earth loop impedance test
RCD switchgear and changeover device	Functional tests

6. Accurate Documentation

A quality job must be well documented, the more important type of documents are summarised as follows:

- Technical Data for the equipment and materials to be used for the project
- Operation Instruction and Maintenance Manual of the Equipment
- Delivery Schedule of the Equipment and Materials
- Site Daily Record Book
- Architect's and Consulting Engineer's instructions
- All drawing record
- Site Stock record
- Minutes of Meetings

7. The Site Organisation Team

The following functions are needed to be performed for a project, be it carried out on site level depends on individual company policy:

Description	Site	Office	Remarks
Selection of material	v	vv	Very often the selection of material by Contractor is carried out at office because of the availability of information pool.
Preparation of shop drawings	vv	vv	The preparation of shop drawings for those items where accurate dimensioning is needed must be prepared on site level, the final putting together into the CAD or in a presentable manner may have to be carried out at office.
Record of documents	vv	v	The keeping of the documents as stated in item 5 above is preferably made at site level, to suit individual company policy sometimes duplicate copies have to be made at office for management's record and reference.
Constructional design	vv	v	The constructional design by Contractors normally refers to the layout of equipment and design of supporting system, etc. all these should preferably be made at site level due to the ease of checking dimensions and relate to Architectural drawings or drawings of other services.

Stock control	vv		This refers to the control of material delivered to site and material taken out for use, this has to be performed at site level.
Coordination of physical location	vv		This has to be carried out at site level for the same reason as Constructional design.
Coordination of sequence of work	vv	v	This may be carried out at office or on site with the supplementary information from each other, preferably this can be made at site level but again this will depend on individual company policy.
Short term programme	vv	v	This is preferably made at site level due to the ease of access to progress information.
Master programme	v	vv	This is normally carried out at office as this may involve sophisticated software that is not normally available at site.
Arrangement of work	vv		This has to be made at site level to ensure better efficiency.
Supervision of workmanship	vv		as above.
Testing of work	vv	v	This has to be carried out at site level except for those carried out at workshop.
As-fitted drawings	vv	vv	Same as the preparation of shop drawings, the as-fitted drawings has to be initiated at site level for easy access to actual as-built condition.
Operation and Instruction Manual	vv	vv	This may be performed on site or at office.

The selection of a suitable site organisation team is to adequately arrange sufficient staff to perform the above function. The main concept is that there is no overlapping of function and the communication channel is clearly defined.

8. Practical Difficulties

Putting aside the issue, of finance, the common difficulties a Contractor faces are the space and time problem.

With the current expensive land value, the usage of every foot will be very carefully examined for its justification financially. Very often, the space for maintenance and future expansion will be sacrificed. This together with the aesthetic requirements that these "ugly" equipments should not be exposed, may lead to heat dissipation problems and to the worst extent, material selected become underrated at the particular situation.

The problem of time constraint is another major issue. Normally, the earlier the job is completed the earlier is the return of investment. The result is to squeeze every critical activities to its shortest possible. This is especially so for concealed conduit workwhich has to go together with the concrete structure which normally lies on the critical path of a project. The worst case is that the lower reinforcement bars is laid in by 5:00 pm and the top layer laid at 8:00 am the next morning, this means all conduit work has to be laid at night with insufficient lighting and that the conditions of the workers are not at their best. Such situation will leave no time for quality assurance test and whether representatives from client will be able to check the correctness of conduit location is very doubtful. We cannot have qualify job on such conditions.

9. Conclusion

The on site quality control of electrical installation mainly depends on the performance of the site management team. Sufficient time for installation, appropriate personnel for monitoring, right material to be used, correct method and tooling for implementation are the major factors. However, financial implication is also another main factor affecting the quality control. The new format of contract will also be fatal to the quality control if it is not properly instrumented. Above all, co-ordination with other trades is a necessity to the good quality control on site. Without this, a good production of building services installation can hardly be achieved.

Paper No. 10

Protection against Environment

Speaker: Dr. H. Y. Yeung, Chief Environmentalist, China Light & Power Co. Ltd.

ENVIRONMENTAL PROTECTION IN THE ELECTRICITY SUPPLY INDUSTRY

by

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1. Introduction

In order to maintain a secure electricity supply to an ever-growing number of consumers at economic cost, China Light & Power has continued to operate and invest in efficient plant for the generation, transmission and distribution of electricity. With the increase in plant size and operation, however, the potential for environmental impact also increases. For example, the construction and operation of the coal-fired Castle Peak Power Stations, with a combined generating capacity of approximately 4,350MW, occupies 69 hectares of coastal and reclaimed land. With a development of this scale, it would be unrealistic to expect there to be no impact on the environment. Consequently, it is necessary to draw up a balance between the requirements for electricity for factories, offices and homes on the one hand and the demands for protection of the environment on the other. Such 'balance sheets' are not always easy to draw up and it is often difficult, if not impossible, to apportion relative costs and benefits to environmental protection measures. How, for example, can one quantify the cost of destroying a particularly sensitive species of plant life by pollution from power station chimneys, or the ecological damage that may result from thermal discharges from a power station cooling system? Difficult though they may be, it is questions such as these that need to be addressed right from the earliest planning stages of major projects undertaken by China Light & Power.

The paper is concerned with the measures that have been taken by China Light & Power to minimize the impact of its operations on the environment. It is hoped that, through illustrative examples of major developments, the reader will become more familiar with some of the basic environmental issues derived from electricity generation and also what can be achieved by prudent management of such projects in order to minimize any adverse environmental impacts. Described below are several developments exemplifing the environmental awareness of the Company.

2. Major Environmental Impacts of Coal-Fired Power Stations

It was apparent to China Light & Power that a new power station would be needed in the 1980s to meet the need for electricity in Hong Kong. It was also apparent to the Company that the construction of what is to be one of the largest coal-fired power stations in southeast Asia deserved a detailed evaluation of the possible environmental impacts from such a major development. Consequently, a series of environmental impact assessment reports (EIA) were produced at the same time that the Castle Peak Power Stations were first designed. In brief, the environmental impacts of a modern coal-fired power station can be conveniently grouped into five main areas: air pollution; water pollution; solid waste; noise and visual intrusion.

2.1 Air Pollution

2.1.1 Air Pollution Impacts

The products of coal combustion can be broadly classified into gases and particulates. For power station boilers the main components are:

* Smoke, which is fine, easily visible carbonaceous material arising from incomplete combustion of fuel;

* Grit and dust, which arise from the mineral impurities present in the fuel;

* Gaseous sulphur oxides, principally SO_2, which arise from the sulphur contained in the fuel;

* Other gaseous components; such as nitrogen oxides.

Combustion gases and particulates are normally dispersed into the atmosphere via a chimney.

2.1.2 Air Pollution Control

Dispersion of gases in the atmosphere is a highly complex process being governed by the laws of physics, chemistry and meteorology. The presence of complex topographical features, such as mountains, makes procedures for prediction of air pollution dispersion problematical and often unreliable. For the Castle Peak 'B' Power Station, it was decided that the situation was too complex to be reliably modelled by mathematical techniques and the alternative approach, physical modelling, was adopted. A physical scale model of the power station site and adjacent land was therefore constructed and wind tunnel tests performed to examine the dispersal of chimney gases over Castle Peak and tue Tuen Mun-Yuen Long Valley. This model was used to examine the effects of changing the chimney height on ground level sulphur dioxide concentrations in Tuen Mun. The design basis was that the ground level sulphur dioxide concentration in Tuen Mun should be no worse than those measured around a power station of comparable design, operating in the United Kingdom. The outcome of the environmental impact assessment process was a final chimney height of 215m for the 'A' Power Station and 250m for the 'B' Power Station. With these chimney heights, modelling indicated that the average ground level sulphur dioxide concentration resulting from the operation of Castle Peak Power Stations would not be increased by more than 8 micrograms per cubic metre of air. Such an increase is insignificant in terms of health hazards to the exposed population, normal variation in daily sulphur dioxide levels being many times greater than this. To complement the tall stack approach of impact reduction, coal with low sulphur content is also being used at Castle Peak Power Stations to reduce the total amount of sulphur compounds being emitted to the atmosphere.

Apart from the dispersion of the gaseous components, the greater part of the particulates in the combustion stream is removed by efficient electrostatic precipitators, a proven technology used by many power stations world-wide. Over 99 percent removal efficiency is achieved at the Castle Peak Power Stations.

2.1.3 Air Pollution Monitoring

An air pollution monitoring network has been established in the north-west New Territories to monitor the impact of the power station air emissions. Data from the monitoring network are submitted to the Hong Kong Government on a regular basis and technical discussions are held to identify areas of concern. Results to date have failed to detect any significant effects of the Castle Peak Power Stations on the air quality. Monitoring will continue throughout the commissioning phase of the 'B' Power Station and for at least two years beyond. At the end of this period, a final evaluation of the impact of the new generating facilities at Castle Peak on air quality will be made.

2.2 Water Pollution

2.2.1 Water Pollution Impacts

The main issue of concern with regard to water pollution from coal-fired power stations is the discharge of heated water used for the cooling of steam in the condenser. In a 'once through' cooling system such as at the Castle Peak Power Stations, water is abstracted from the surrounding sea at ambient temperature to feed the condensers. A total of 128 cubic metres of water is needed per second for the steam condensation process and this water is discharged back to the environment through the cooling water outfalls at approximately ten degrees Centigrade above ambient. As temperature has a profound effect on biological processes, it is understandable that concern should arise over the possible harmful effects of the heated discharge.

Other water pollution impacts that need to be assessed at the design stage are of lesser significance than thermal pollution generally. They include such things as coal store drainage, ash pit discharges, water treatment plant effluent, sewage and general surface drainage. These impacts were studied in depth during the environmental impact assessment of Castle Peak Power Stations and significant adverse impacts were not identified.

2.2.2 Water Pollution Control

A comprehensive system of water pollution treatment was designed for each of the waste streams. This means standard technique such as solid sedimentation, chemical flocculation, pH neutralisation, dilution and phase separation are used where appropriate to ensure the station's liquid discharges conform to established standards of the Hong Kong Government.

2.2.3 Water Pollution Monitoring

Although the results of environmental impact studies of thermal pollution carried out elsewhere indicate limited adverse effects, there is insufficient scientific data on the ecology of Hong Kong's coastal environment to draw up a similar conclusion for the Castle Peak Power Stations. In view of this, detailed local studies were conducted at Tap Shek Kok to delineate the actual thermal impacts of the cooling water discharge. The research conducted involves collecting samples of the seabed at various positions corresponding to the distribution of the heat field over a period of two years with identifications of temporal changes of faunal compositions. At the same time, measurements of various hydrographical parameters, such as temperature, salinity, dissolved oxygen, suspended solids, pH and current movements, enable the effects of natural phenomena to be identified in addition to any that may arise from the thermal discharge.

2.3 Other Impacts

Other impacts from the Power Stations, besides air and water pollution, encompass the areas of noise, visual intrusion, and ash disposal. Through a combination of careful design, proper operations and installation of abatement measures, noise impact could be minimized to an acceptable level at the plant boundary line. The visual impact of the Power Stations is minimized through optimal layout to blend in with the local environment and extensive revegetation of disturbed land and slopes. Evidence of the success of the approach taken is now readily seen at the Power Stations. Lastly, the requirement for the proper disposal of ash derived from the burning of coal at the Power Stations is a major topic in itself and its likely environmental impacts are therefore described in the following sections.

3. Tsang Tsui Ash Lagoon

The majority of the constituents of coal are combustible but approximately 10–15% by weight is in the form of inert ash which is left over as a solid by-product of the combustion process. Over eighty percent of this ash forms a fine dust-like material which is separated by the electrostatic precipitators from the boiler gases and is known as pulverized fuel ash (PFA). The balance of the ash is a much coarser material which falls out of the gas stream in the furnace and is known as furnace bottom ash (FBA). The amount of PFA produced is dependent upon a number of factors but is typically of the order of 1 tonne per megawatt of electricity generated per day. Thus for the fully operational Castle Peak Power Stations, this represents a maximum PFA production of about 4000 tonnes per day at peak load. Finding a site for the safe disposal of such large quantities of ash is extremely difficult considering Hong Kong's acute land shortage. A site was eventually identified at Tsang Tsui, in the northwest New Territories, whereby a sea lagoon was constructed by China Light & Power to provide for the storage of the ash produced.

3.1 Environmental Impacts

The environmental issues of concern with regard to ash storage schemes tend to centre on air and water pollution. Air pollution impacts can arise during either the transport of ash from the power station to the storage site or at the storage site itself. If ash is allowed to dry out, it can easily become airborne and create a severe dust nuisance.

PFA can be enriched in a number of elements, depending upon the origin of the coal. One group of elements, the so-called heavy metals, are of special interest because of the toxic effects they may have when inhaled or ingested by humans and other animals. In order for these potentially toxic heavy metals to have an adverse impact on the environment, a pathway must be provided whereby the metals can be transferred from the ash to the receptor. Such a pathway could be provided whereby the metals can be transferred from the ash to the receptor. Such a pathway could be provided by dissolution of metals in seawater used for ash slurry production. Subsequent discharge of this metal enriched seawater could provide a direct route for uptake of metals by marine organisms. Thus, one concern about the Tsang Tsui ash lagoon was whether heavy metal releases from the lagoon would result in metals being taken up by oysters being cultured commercially in Deep Bay.

3.2 Environmental Control

A great deal of attention was paid to the concern over air and water pollution from the ash lagoon. With regard to the transport of ash from the Power Stations to Tsang Tsui, the problem of air pollution was eliminated by transferring the ash as a liquid slurry in a pipeline connecting the two sites. Control of the fugitive dust problem at the ash lagoon site is achieved by means of water spraying devices and by the establishment of a soil and vegetative cover on the ash pile.

With regard to water pollution, a detailed research investigation was launched to study the possible uptake of metals by Deep Bay oysters. Various computer modelling studies were also carried out to evaluate the extent of any possible increment in metal loading of Deep Bay, if the slurry water were to be directly discharged at the Tsang Tsui site.

From the various environmental investigations, independent environmental consultants, retained by China Light & Power, concluded that the increase in metal burden resulting from both discharges and leachate from the lagoon, would amount to less than one percent of the existing metal load of Deep Bay. Furthermore, the consultants concluded that such a small additional input of trace metals would not result in significant contamination of Deep Bay oysters. Notwithstanding these findings, and acknowledging the complexity of the scientific uncertainties surrounding such assessments, China Light & Power decided to introduce mitigation measures into the scheme to remove any possibility of trace metal contamination of Deep Bay. These measures included the provision of an impervious membrane to line the lagoon walls, thus preventing leachate passing through, and the pumping back of the slurry water to Castle Peak. The pump back option is designed to increase the dilution of slurry water by mixing with the large volumes of cooling water being continuously discharged at the power stations. Together with natural dilution and dispersion in the seawater itself, this scheme will ensure that trace metal contaminants of the slurry water will be dispersed harmlessly in minute concentrations and not affect marine life.

3.3 Environmental Monitoring Programme

To ensure that all adverse air impacts were identified and corrected during the operation of the lagoon, air sampling stations were established at the perimeter of the lagoon to monitor fugitive dust levels on a routine basis. Both passive deposition and high volume sampling instruments are being used to sample the dust burden in air. The dust compositions in the samples were subsequently examined microscopically in the laboratory to determine the contribution from fugitive ash. So far, ash was not found to be a significant portion of the collected dust.

A long term biological monitoring study is also in progress to monitor the metal levels in the Deep Bay oysters. Seven marine buoys with experimental oysters attached and placed along a linear transect stretched between the Power Stations and the head of Deep Bay, were established to provide samples of oysters for the determination of metal uptake. Results to date indicated that there is no discernable increase of metals in the oysters apart from those of natural fluctuations.

4. Removal of PCB Transformers

On 21st June, 1988, China Light & Power has completed its programme of removing 101 Polychlorinated biphenyl (PCB) distribution transformers from consumer electricity substations. PCB was commercially available in the 1930's and has since been widely used by industry because of its non-inflammable characteristics. However, by the late 1970's, scientific researches had indicated possible potential harmful effects of the chemical especially after it undergoes incomplete combustion. This led to the decision made by China Light & Power to replace all distribution transformers containing PCB. PCB transformers removed are shipped to the United Kingdom for proper disposal by incineration of the PCB material at high temperature.

5 Other Environmental Studies

Apart from the main programmes described above, China Light & Power also runs a number of other programmes which have been developed to investigate specific issues. Examples of such efforts include: assessment of fugitive dust releases from coal stock-piles; heavy metal content and particulate concentrations of coal stock run-off; noise levels of electricity substations and performance testing of packaged sewage treatment plant.

6 Concluding Remarks

In parallel with the increase in industrial growth in Hong Kong, the aspirations of the general public for a clean and healthy environment are also growing. Greater affluence invariably leads to greater awareness of environmental issues as expectations in life tend to increase with increases in the standards of living. Experience of similar developments in the 1960's and 70's in Europe and North America are useful in assessing Hong Kong's position and specific requirements. China Light & Power has continued to keep pace with the growing demands for a better environment and has established the necessary facilities and expertise to pursue a comprehensive environmental protection policy. The major facet of the work is good environmental planning so that future problems do not arise. Careful deliberations about the possible impacts of the new developments ensure that unforeseen pollution problems do not occur from the developments. Indeed, there is a major economic incentive in such environmental planning as it is always more costly to resolve a problem after construction than at the design stage. China Light & Power has always set up comprehensive pollution monitoring programmes for its many developments. These programmes provide the necessary data for assessing the impacts of the new developments. It is strongly believed by China Light & Power that the Company's primary responsibility the provision of electricity at economic cost can be discharged without adverse environmental effects on Hong Kong's environment.