Electrical Installation Technology

SECOND EDITION

2

Maurice Lewis

Electrical Installation Technology 2

Second Edition

Maurice L. Lewis
BEd (Hons), MIElecIE
Course 236 Tutor in Electrical Installation Work
at Luton College of Higher Education

Hutchinson

London Melbourne Sydney Auckland Johannesburg

Hutchinson & Co. (Publishers) Ltd
An imprint of the Hutchinson Publishing Group
17–21 Conway Street, London W1P 6JD

Hutchinson Group (Australia) Pty Ltd
30–32 Cremorne Street, Richmond South, Victoria 3121
PO Box 151, Broadway, New South Wales 2007

Hutchinson Group (NZ) Ltd
32–34 View Road, PO Box 40–086, Glenfield, Auckland 10

Hutchinson Group (SA) (Pty) Ltd
PO Box 337, Bergvlei 2012, South Africa

First published 1980
Reprinted 1982
Second edition 1984

Set in VIP Times Roman by Preface Ltd, Salisbury, Wilts.

Printed and bound in Great Britain by
Anchor Brendon Ltd,
Tiptree, Essex

British Library Cataloguing in Publication Data
Lewis, M.L.
Electrical installation technology.
2 – 2nd ed.
1. Electric engineering
1. Title
621.3 TK 145

ISBN 0 09 153151 9

Contents

Preface 7

Acknowledgements 8

chapter one
Health and safety 9

Health and Safety at Work etc. Act Electricity safety regulations Safe working procedure Accident reporting *Exercise 1* Other Factories Act Regulations Useful terminology Further reading

chapter two
Communication and industrial studies 23

Purpose of bar charts Contract documents Specifications Variations Bills of quantities Site organization Industrial relations Customer relations Records Interpretations of drawings *Exercise 2* Useful terminology

chapter three
Distribution 33

Control of supply voltage Selection of switchgear and cables Ring and rising mains Earthing methods Switchboard instruments Power factor *Exercise 3* Useful terminology

chapter four
Semiconductor devices 47

Basic theory of semiconductors Diode Transistor Thyristor Triac and diac *Exercise 4* Useful terminology

chapter five
Installation of motors 58

Three-phase induction motor Single-phase induction motor Example 1 Example 2 Commutator motors Direct current motors Three-phase induction motor starters Direct current motor starters Installation Maintenance *Exercise 5* Useful terminology

chapter six
Installation of lighting 81

Light Incandescent lamps Tungsten-halogen lamps Discharge lamps Low-pressure mercury fluorescent lamp High-pressure mercury fluorescent lamp Low-pressure sodium vapour lamp High-pressure sodium vapour lamp General lamp hints Regulation requirements High-voltage installations Emergency lighting Illumination calculations Laws of illumination Lumen method calculations Spacing/mounting-height ratio Measuring light *Exercise 6* Lighting calculations Useful terminology Lamp letter codes

chapter seven
Inspection and testing 107

Test requirements The ohmmeter Tong tester *Exercise 7* Useful terminology

chapter eight
Multiple-choice questions test paper 117

Answers to exercises 128

Answers to multiple-choice questions test paper 129

Index 130

Electrical Installation Technology 2

by the same author

Electrical Installation Technology 1
Electrical Installation Technology 3
Multiple Choice Questions in Electrical Installation Work

Electrical Installation Technology 2

Second Edition

Maurice L. Lewis
BEd (Hons), MIElecIE
Course 236 Tutor in Electrical Installation Work
at Luton College of Higher Education

Hutchinson

London Melbourne Sydney Auckland Johannesburg

Hutchinson & Co. (Publishers) Ltd
An imprint of the Hutchinson Publishing Group
17–21 Conway Street, London W1P 6JD

Hutchinson Group (Australia) Pty Ltd
30–32 Cremorne Street, Richmond South, Victoria 3121
PO Box 151, Broadway, New South Wales 2007

Hutchinson Group (NZ) Ltd
32–34 View Road, PO Box 40–086, Glenfield, Auckland 10

Hutchinson Group (SA) (Pty) Ltd
PO Box 337, Bergvlei 2012, South Africa

First published 1980
Reprinted 1982
Second edition 1984

Set in VIP Times Roman by Preface Ltd, Salisbury, Wilts.

Printed and bound in Great Britain by
Anchor Brendon Ltd,
Tiptree, Essex

British Library Cataloguing in Publication Data
Lewis, M.L.
Electrical installation technology.
2 – 2nd ed.
1. Electric engineering
1. Title
621.3 TK 145

ISBN 0 09 153151 9

Contents

Preface 7

Acknowledgements 8

chapter one
Health and safety 9

Health and Safety at Work etc. Act Electricity safety regulations Safe working procedure Accident reporting *Exercise 1* Other Factories Act Regulations Useful terminology Further reading

chapter two
Communication and industrial studies 23

Purpose of bar charts Contract documents Specifications Variations Bills of quantities Site organization Industrial relations Customer relations Records Interpretations of drawings *Exercise 2* Useful terminology

chapter three
Distribution 33

Control of supply voltage Selection of switchgear and cables Ring and rising mains Earthing methods Switchboard instruments Power factor *Exercise 3* Useful terminology

chapter four
Semiconductor devices 47

Basic theory of semiconductors Diode Transistor Thyristor Triac and diac *Exercise 4* Useful terminology

chapter five
Installation of motors 58

Three-phase induction motor Single-phase induction motor Example 1 Example 2 Commutator motors Direct current motors Three-phase induction motor starters Direct current motor starters Installation Maintenance *Exercise 5* Useful terminology

chapter six
Installation of lighting 81

Light Incandescent lamps Tungsten-halogen lamps Discharge lamps Low-pressure mercury fluorescent lamp High-pressure mercury fluorescent lamp Low-pressure sodium vapour lamp High-pressure sodium vapour lamp General lamp hints Regulation requirements High-voltage installations Emergency lighting Illumination calculations Laws of illumination Lumen method calculations Spacing/mounting-height ratio Measuring light *Exercise 6* Lighting calculations Useful terminology Lamp letter codes

chapter seven
Inspection and testing 107

Test requirements The ohmmeter Tong tester *Exercise 7* Useful terminology

chapter eight
Multiple-choice questions test paper 117

Answers to exercises 128

Answers to multiple-choice questions test paper 129

Index 130

Preface

This is the second textbook for electrical installation work students who are pursuing the City and Guilds Course 236. Whereas the first volume concentrated on topics appearing in the Part I syllabus, this volume is written around areas appearing in the Part II syllabus: the scheme leading to the award of the Electrician's Certificate subject to passing the new JIB approved achievement measurement test two.

Each chapter, like the previous edition, begins with a number of objectives intended for easy guidance on selected topics. Chapter 1 reviews health and safety requirements and looks at electrical safety from both the Electricity (Factories Act) Special Regulations 1908 and 1944, and the 15th Edition of the IEE Wiring Regulations 1981. Safe working procedures and accident reporting are also included.

Chapter 2 is concerned with communication and industrial studies and relates to topics around electrical contracting and site organization. Chapter 3 covers electrical distribution where ring main and rising main systems are discussed along with earthing systems, switchboard instruments and power factor.

Chapter 4 covers semiconductor devices, such as p.n. diodes, transistors and thyristors, while Chapter 5 provides information on motor installations, particularly the principles of operation of common a.c./d.c. types, their starting and speed control.

Chapter 6 deals with lighting installations covering numerous lamp types, their operation and circuitry as well as safety requirements. In Chapter 7 a review is made of inspection and testing together with test instruments. The final chapter is devoted to a typical multiple-choice question paper based on 70 items. The answers to these and other exercises are given at the back of the book.

It is hoped that electrical students following City and Guilds Course 232 and TEC students will find this book of immense value.

M.L.L.

Acknowledgements

The author wishes to thank a number of manufacturers and organizations who have contributed information to make this book possible, particularly:

AEI Cables Ltd
AEI Semiconductors Ltd
Avo Ltd
British Standards Institution
Brook Motors Ltd
Crompton Instruments Ltd
Crompton Parkinson Ltd
Eversheds & Vignoles Ltd
IPC Electrical-Electronic Press Ltd
J. A. Crabtree Ltd
Mawdsley's Ltd
Midland Electric Manufacturing Co Ltd
MK Electric Ltd
Ottermill Switchgear Ltd
Reyrolle Ltd
The Institution of Electrical Engineers
Thorn Lighting Ltd

The author also wishes to thank Mr E. P. Guinn, Mr A. C. Hatfield, Mr A. H. P. Hall, Mr T. A. Lovelock, Mr D. W. Withey, Mr E. Davies and Mr A. H. Blackboro (on behalf of the ASEE) for their helpful comments

chapter one

Health and safety

After reading this chapter you will be able to:

1 State the duties of both employer and employee with regard to the Health and Safety at Work etc. Act 1974.

2 Explain the requirements of the Electricity (Factories Act) Special Regulations 1908 and 1944 with regard to the following:
   a) apparatus and conductors
   b) fuses and automatic circuit breakers
   c) joints and connections
   d) excess current protection
   e) control of motors
   f) flexible wires for portable apparatus

3 State the purpose of the IEE Wiring Regulations.

4 Describe safe working procedures on or about live equipment.

5 Know the procedure for treatment of electric shock.

6 Know the procedure for reporting accidents.

7 Know the procedure for treatment of wounds.

Health and Safety at Work etc. Act

In *Electrical Installation Technology 1*, reference was made to the Health and Safety at Work etc. Act 1974. The Act was a result of recommendations made by a Royal Commission in 1970 which looked at the whole field of health and safety at work and came to the conclusion that apathy was the main cause of accidents.

The law as it stood was insufficient and the Commission believed that the Factory Inspectors were faced with a difficult, if not impossible, task of being 'all purpose technical advisers' over the whole range of industry. On 1 January, 1975 the Factory Inspectorate, the Mines and Quarries Inspectorate, the Nuclear Installations Inspectorate, the Alkali Inspectorate and the Employment Medical Advisory Service were all transferred to the Health and Safety Executive (HSE); by March 1977, this included the Agricultural Inspectorate.

The Act itself provides a comprehensive legal framework which embraces the health and safety of almost everyone at work and also protects the public at large from the risks arising out of work activities.

Duties placed on an *employer* include:

the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risk to health.

(Sect. 2(2)(a))

arrangements for ensuring, so far as is reasonably practicable, safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances.

(Sect. 2(2)(b))

the provision of such information, instruction, training and supervision as is necessary to ensure, so far as is reasonably practicable, the health and safety at work of his employees.

(Sect. 2(2)(c))

so far as is reasonably practicable as regards any place of work under the employer's control, the maintenance of it in a condition that is safe and without risks to health and the provision and maintenance of means of access to and egress from it that are safe and without such risks.

(Sect. 2(2)(d))

the provision and maintenance of a working environment for his employees that is, so far as is reasonably practicable, safe, without risks to health and adequate as regards facilities and arrangements for their welfare at work.

(Sect. 2(2)(e))

Duties placed on an *employee* include:

the taking of reasonable care for the health and safety of himself and other persons who may be affected by his acts or omissions at work.
Cooperation with his employer or any other person to enable a statutory provision or requirement to be performed or complied with.

It is obvious that the Act requires every employer and employee to be much more safety conscious. An employer is required to prepare a written statement of general policy on matters concerning health and safety at work. It should be in the form of a declaration of the employer's intent to provide the safest and healthiest working conditions possible: this being achieved with the help and support of his employees.

The Act created two corporate bodies, namely the Health and Safety Commission (HSC) and the Health and Safety Executive (HSE). The HSC is responsible to the Secretary of State and functions on a consultative basis. It has the power to make arrangements which it considers appropriate for the general purpose of the Act. For example, it prepares Codes of Practice which provide practical guidance on the requirements of the Act; it may also propose new regulations, such as the Safety Representatives and Safety Committees Regulations 1977. The HSE, on the other hand, is responsible for the *enforcement* of the Act and in addition provides an advisory service to both employer and employee. Enforcement of the Act may also be the responsibility of another authority, such as a Local Authority, but in either case, inspectors are appointed having certain powers to enter any premises, collect evidence from it, issue improvement and prohibition notices; they even have the power to seize or destroy articles or substances which are considered to be a source of imminent danger likely to cause serious personal injury.

The Act also provides criminal penalties for those who do not satisfy the requirements or perform the duties imposed by the regulations made under it. The maximum fine on summary conviction in a magistrates' court for most offences is £400 but there is no limit to the fine on conviction on indictment in a crown court. Imprisonment for up to two years can be imposed for certain offences.

Electricity safety regulations

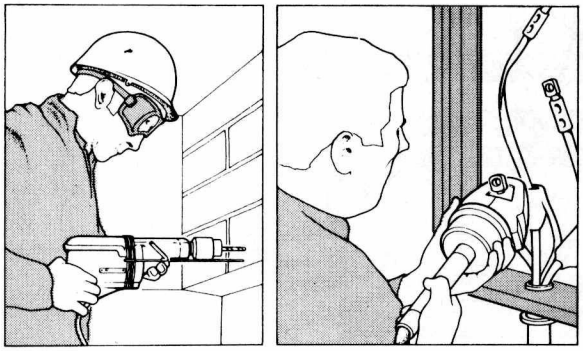
There are two important documents which electrical students should read in connection with their work. These are:

a) The *Electricity (Factories Act) Special Regulations* 1908 and 1944
b) The *IEE Regulations for Electrical Installations* (15th Edition) 1981.

The Electricity Regulations contain the mandatory requirements which ensure the safe utilization of electrical energy in *factories*. The detailed means by which these requirements are satisfied are contained in publications published by the British Standards Institution and by the Institution of Electrical Engineers (IEE). The regulations which are relevant to the content of this book are Regulations 1–13 inclusive and 21, 28 and 29.

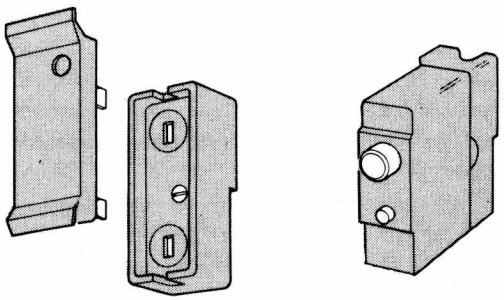
Reg. 1 *All apparatus and conductors shall be sufficient in size and power for the work they are called upon to do, and so constructed, installed, protected, worked and maintained as to prevent danger so far as is reasonably practicable.*
Briefly, this regulation places a general responsibility on the occupier of a factory for the safety and safe working of his installation. Apparatus and conductors should be carefully selected and properly installed and maintained by a competent person or contractor. The regulation applies to a.c. and d.c. systems at any voltage. Apparatus, for example, must be capable of safely withstanding the electro-thermal and electromagnetic effects of any short circuit which may occur. Apparatus must be made to a suitable standard, being safely constructed for the conditions under which it will be used.

It is essential to provide routine examination of electrical equipment. Switchgear and other protective devices such as circuit breakers and tripping relays require regular inspection and testing to confirm that they will operate reliably under adverse



(a) (b)

Figure 1 *Taking care using portable tools*
a) Wearing protective gear
b) Showing a safe termination method



(a) (b)

Figure 2 *The safe construction of*
a) a rewireable fuse and fuseholder
b) miniature circuit breaker

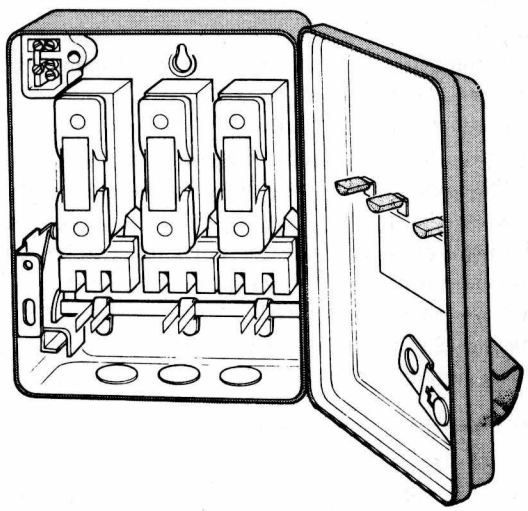


Figure 3 *TPN switchfuse showing internal arrangements*

conditions. Earthing of exposed metalwork is important and so too is the need to have circuit isolation when working on *live* conductors. It should be made clear that the responsibility for any accidents may be placed upon workmen if they fail to make use of any safety equipment provided (Figure 1).

A few other important regulations are: Regs. 5, 6, 8, 12 and 13. For further information reference should be made to the explanatory *Memorandum on the Electricity Regulations* (HMSO). Other factory regulations are stated on page 21.

Reg. 5 *Every fuse, and every automatic circuit breaker used instead thereof, shall be so constructed and arranged as effectively to interrupt the current before it so exceeds the working rate as to involve danger. It shall be of such construction or be so guarded or placed as to prevent danger from overheating, or from arcing or the scattering of hot metal or other substance when it comes into operation. Every fuse shall be either of such construction or so protected by a switch that the fusible metal may be readily renewed without danger* (Figure 2).
In this regulation the protective device must be capable of dealing with normal overloads and also short circuit conditions, as previously mentioned in Reg. 1 above. Fuses protecting a motor circuit must be satisfactorily constructed to avoid injury to persons and/or fire from overheating, arcing or scattering of hot metal or other substances. The injury a person is most likely to receive is that of electric shock, therefore complete protection of all live metal on the fuseholder and its contacts is required in the design construction. Alternative protection can only be secured by a switch in the live or supply side of the fuses, arranged to break in each pole and preferably with an interlocking device, whereby the fusebox can be opened only when the switch is in the *off* position (Figure 3).

Reg. 6 *Every electrical joint and connection shall be of proper construction as regards conductivity, insulation, mechanical strength and protection.*
Concern in this regulation is for every joint and connection to have at least the same properties (as indicated) as the system or circuit of which it forms part. It is not permissible just to twist conductors together, they need to be made mechanically sound by soldering, brazing, welding or mechanically

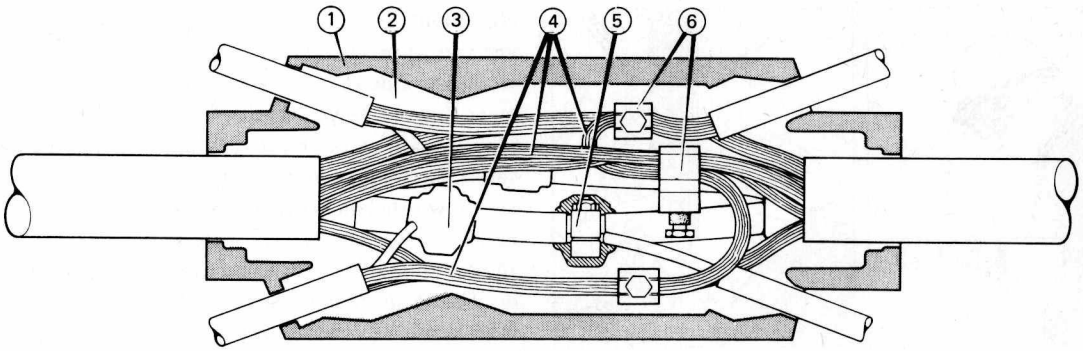


Figure 4 *Waveformal multi-service joint conforming to Factories Act Regulation 6 (Courtesy AEI cables)*
1 Plastics protection box
2 Cold pouring resin compound
3 Mastic pad insulation
4 Neutral/earth conductors
5 Mechanical phase connector
6 Mechanical neutral/earth connector

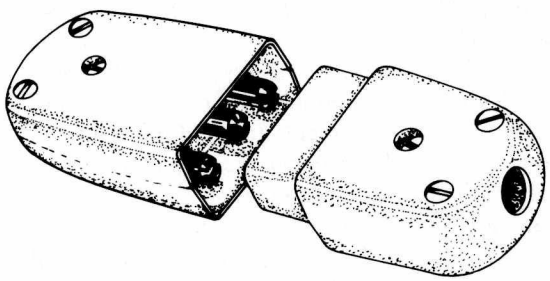


Figure 5 *Flex connector (non-reversible with cord grip)*

clamping together. The last method may take the form of a compression joint. It is important that all joints securely retain all strands and wires of conductors (Figure 4). Flexible cables and flexible cords should not be *jointed* but cable couplers and connectors can be used.

Precautions should be taken against corrosion, especially where aluminium and copper conductors are joined together. An aluminium conductor should not come into contact with a brass terminal unless it is suitably plated. Joints in earthing conductors are also important. Such joints must ensure good conductivity to allow the passage of escaping earth currents. It is very important to make earth continuity conductor tests on metal conduit and metal sheathing of cables, metal trunking and all earth wires.

Reg. 8 *Efficient means suitably located shall be provided for protecting from excess of current every part of a system, as may be necessary to prevent danger.*

In this regulation, efficient protective gear must be provided to safeguard against the risk of electric shock and fire. Important considerations in the selection of protective gear are: *the nature of the circuits and type of apparatus to be protected* (this may range from high voltage systems, e.g. in substations, to low voltage systems, e.g. final circuits supplying lamps), *the nature of the process carried out* (the degree of protection may vary from one industrial process to the next depending upon the work being carried out). To avoid the risk of fire, short circuits or earth faults should be cleared promptly. Protective apparatus, such as circuit breakers and fuses, should be set at the minimum value in relation to the load current. It is generally advisable to incorporate some form of earth leakage protection to ensure operation at minimum current. Also, *the nature and efficiency of the earthing system* might be seen as another important factor and so too *the short circuit energy available in the supply.*

Note: Protection against electric shock is shown in Figure 6.

Reg. 12 *Every electric motor shall be controlled by an efficient switch or switches for starting or stopping, so placed as to be easily worked by the person in charge of the motor.*