NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical & Electronic Engineering

Internal Electrical Installation Project

Graduation Project
EE 400

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Date: 05.02.07

Abstract

Starting to draw the electrical project, architectural plan and measurements were studied. The locations of house hold devices were decided.

The illumination calculations for rooms have been done and suitable devices along with their amounts were selected.

Wiring methods, insulation properties, safety rules, cable types were studied due to their importance over an internal electrical installation project and also explained in the report.

Also historical and trivial information have been added about the subject.

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Electrical Wiring

Electrical wiring in general refers to insulated conductors used to carry electricity, and associated devices. This article describes general aspects of electrical wiring as used to provide power in buildings and structures, commonly referred to as building wiring.

Wiring Safety Codes

Electrical codes arose in the 1880s with the early commercial introduction of electrical power. Many conflicting standards existed for the selection of wire sizes and other design rules for electrical installations. The intention of wiring safety codes is to provide safeguarding of persons and property from hazards arising from the use of Regulations may be set by local city, provincial/state or national legislation, perhaps by amendments to a model code produced by a technical standards-setting organization, or by a national standard electrical code.

The first electrical codes in the United States originated in New York in 1881 to regulate installations of electric lighting. Since 1897 the U.S. National Fire Protection Association, a private nonprofit association formed by insurance companies, publishes the National Electrical Code (NEC). States, counties or cities often include the NEC in their local building codes by reference along with local differences. The NEC is modified each three years. It is a consensus code considering suggestions from interested parties. The proposals are studied by Committees of engineers, tradesmen, manufacturer representatives, fire fighters, and other invitees.

Since 1927, the CSA (Canadian Standards Association) has produced the Canadian *Safety Standard for Electrical Installations*, which is the basis for provincial electrical codes.

Although these two national standards deal with the same physical phenomena and broadly similar objectives, they differ occasionally in technical detail. As part of the NAFTA(The North American Free Trade Area) is the trade block created by the North American Free Trade Agreement (NAFTA) and its two supplements, the North American Agreement on Environmental Cooperation (NAAEC) and the North American Agreement on Labor Cooperation (NAALC) whose members are Canada, Mexico and the United States. It came into effect on 1 January 1994) program, US and Canadian standards are slowly converging towards each other, in a process known as harmonization.

In European countries, an attempt has been made to harmonize national wiring standards in an IEC standard, IEC 60364 *Electrical Installations for Buildings*. However, this standard is not written in such language that it can readily be adapted as a national wiring code. Neither is it designed for field use by electrical tradesmen and inspectors for acceptance of compliance to national wiring standards. National codes, such as the NEC or CSA C22.2, exemplify the common objectives of IEC 60364, and provide rules in a form that allows for guidance of persons installing and inspecting electrical systems.

The 2006 edition of the Canadian electrical code references IEC 60364 and states that the code addresses the fundamental principles of electrical protection in Section 131. The Canadian code reprints Chapter 13 of IEC 60364 and it is interesting to note that there are no numerical criteria listed in that chapter whereby the adequacy of any electrical installation can be assessed.

DKE - German Commission for Electrical, Electronic & Information Technologies of DIN (the German Institute for Standardization) and VDE (German Association for Electrical, Electronic and Information Technologies) - is the German organization responsible for the elaboration of electrical standards and safety specifications.

In the United Kingdom wiring installations are regulated by the produced by the IEE *Requirements for Electrical Installations: IEE Wiring Regulations, BS 7671: 2001* which is now in its 16th edition. The first edition was published in 1882.

Wiring Methods

Materials for wiring interior electrical systems in buildings vary depending on:

- Intended use and amount of power needed of the circuit
- Type of occupancy and size of the building
- National and local regulations
- Environment in which the wiring must operate.

Wiring systems in a single family home or duplex, for example, are simple, with relatively low power requirements, infrequent changes to the building structure and layout, usually with dry, moderate temperature, and no corrosive environmental conditions. In a light commercial environment, more frequent wiring changes can be expected, large apparatus may be installed, and special conditions of heat or moisture may apply. Heavy industries have more demanding wiring requirements, such as very large currents and higher voltages, frequent changes of equipment layout, corrosive, or wet or explosive atmospheres.

Early Wiring Methods

The very first interior power wiring systems used conductors that were bare or covered with cloth, which were secured by staples to the framing of the building or on running boards. Where conductors went through walls, they were protected with cloth tape. Splices were done similarly to telegraph connections, and soldered for security. Underground conductors were insulated with wrappings of cloth tape soaked in pitch, and laid in wooden troughs which were then buried. Such wiring systems were unsatisfactory due to the danger of electrocution and fire, and due to the high labor cost for installation.

Knob & Tube

The earliest standardized method of wiring in buildings, in common use from about 1880 to the 1930s, was *knob and tube* (K&T) wiring: single conductors ran through cavities between the structural in walls and ceilings, with ceramic tubes forming protective channels through joists and ceramic knobs to provide air between the wire and the lumber, and to support the wires.

Other Historical Wiring Methods

Other methods of securing wiring that are now obsolete include:

- Re-use of existing gas pipes for electric lighting. Insulated conductors were pulled into the pipes feeding gas lamps.
- Wood moldings with grooves cut for single conductor wires. These were eventually prohibited in North American electrical codes by the 1930s, but may still be permitted in other regions.

Cables

The first cables for building wiring were introduced in 1922. These were two or more solid copper wires, with rubber insulation, woven cotton cloth for protection of the insulation, then likewise for the overall jacket, usually impregnated with tar as a protection from moisture. Waxed paper was used as fillers and separators. By the 1940s, the labor cost of installing two conductors rather than one cable resulted in a decline in new knob-and-tube installations.

Insulation of these cables was made of rubber. Rubber-insulated cables become brittle over time due to exposure to oxygen, so they must be handled with care, and should be replaced during renovations. When switches, outlets or light fixtures are replaced, the simple act of tightening connections may cause insulation to flake off the conductors. Rubber was hard to separate from bare copper, so copper was tinned.

From the late 1950s, PVC insulation and jackets were introduced, especially for house wiring. About the same time, single conductors with a thinner PVC insulation and a thin nylon jacket became common.

Aluminium wire was common in North American residential wiring from the late 1960s to mid 1970s, due to the rising cost of copper. Due to its greater resistivity, aluminium wiring will typically use one wire gauge larger conductors than would be required of copper - instead of 14 AWG (American wire gauge) for most lighting circuits, aluminium wiring would typically be 12 AWG on a typical 15 amp circuit, though local building codes may vary.

Aluminium conductors were originally used with wiring devices intended for copper wires. Some wiring devices overheated and caused fires. Revised standards for wiring devices were developed to reduce this problem.

Aluminium conductors are still used for power distribution because they cost less than copper wiring, especially in large sizes needed for heavy current loads. Proper installation techniques are required to prevent oxidation and heating of terminations of aluminium conductors.

The simplest form of cable is two insulated conductors twisted together to form a unit; such unjacketed cables with two or three "covered" conductors are used for low-voltage signal and control applications such as doorbell wiring. In North American practice an overhead cable from a transformer on a power pole to a residential electrical service is three twisted (triplexed) wires, often with one being a bare neutral, the other two being "covered" with no voltage rating.

Modern Wiring Materials

Modern nonmetallic sheathed cables (NMC), like (US and Canadian) Type NM, consist of two to four thermoplastic insulated wires and a bare wire for grounding (bonding) surrounded by a flexible plastic jacket.

Rubber-like synthetic polymer insulation is used in industrial cables and power cables installed underground because of its superior moisture resistance.

Insulated cables are rated by their allowable operating voltage and their maximum operating temperature at the conductor surface. A cable may carry multiple usage ratings for applications, for example, one rating for dry installations and another when exposed to moisture or oil.

Generally single conductor building wire in small sizes is solid wire, since the wiring is not required to be very flexible. Building wire conductors larger than #10AWG (or about 6 square millimeters) are stranded for flexibility during installation.

Industrial cables for power and control may contain many insulated conductors in an overall jacket, with helical tape steel or aluminum armor, or steel wire armor, and perhaps as well an overall PVC or lead jacket for protection from moisture and physical damage. Cables intended for very flexible service or in marine applications may be protected by woven bronze wires. Signal cables, such as Ethernet cables, that must be run in air-handling spaces (plenums) of office buildings may be required to be fire-resistant and made with Teflon or other materials that produce little toxic fumes or smoke.

For some industrial uses in steel mills and similar hot environments, no organic material gives satisfactory service. Cables insulated with compressed mica flakes are sometimes used. Another form of high-temperature cable is a mineral insulated cable, with individual conductors placed within a copper tube, and the space filled with magnesium oxide powder. The whole assembly is drawn down to smaller sizes, which compresses the powder. Such cables are fireproof and can be used up to 200 °C, but are costly to purchase and install, and have little flexibility.

Because conductors in a cable cannot dissipate heat as easily as single insulated conductors, they usually are rated at a lower "ampacity". Tables in electrical safety codes give the maximum allowable current for a particular size of conductor, for the voltage and temperature rating of the insulation, and for a given physical environment. The allowable current will be different for wet or dry, for hot (attic) or cool (underground) locations. In a run of cable through several areas, local electrical codes will determine the proper rating of the overall run.

Cables usually are secured by special fittings where they enter electrical apparatus; this may be a simple screw clamp for jacketed cables in a dry location, or a polymer-casketed cable connector that mechanically engages the armor of an armored cable and provides a water-resistant connection. Special cable fittings may be applied to prevent explosive gases from flowing in the interior of jacketed cables, where the cable passes through areas where flammable gases are present. To prevent loosening of the connections of individual conductors of a cable, cables must be supported near their entrance to devices and at regular interval through their length. In tall buildings special designs are required to support the conductors of vertical runs of cable. Usually, only one cable per fitting is allowed. Special cable constructions and termination techniques are required for cables installed in ocean-going vessels; in addition to electrical safety and fire safety, such cables may also be required to be pressure-resistant where they penetrate bulkheads of a ship.

Raceways

Insulated wires may be run in one of several forms of a raceway between electrical devices. This may be a pipe, called a conduit, or in one of several varieties of metal (rigid steel or aluminum) or non-metallic (PVC) tubing. Wires run underground, for example, may be run in plastic tubing encased in concrete, but metal elbows may be used in severe pulls. Wiring in exposed areas, for example factory floors, may be run in cable trays or rectangular raceways having lids. Where wiring, or raceways that hold the wiring traverse fire-resistance rated walls and floors, the openings are required by local building codes to be fire stopped. In cases where the wiring has to be kept operational during an accidental fire, circuit integrity fireproofing must be applied in a bounded manner to comply with the law. The nature and thickness of any passive fire protection materials used in conjunction with wiring and raceways has a quantifiable impact upon the ampacity derating. Special fittings are used for wiring in potentially explosive atmospheres.

Cable trays are used in industrial areas where many insulated cables are run together. Individual cables can exit the tray at any point, simplifying the wiring installation and reducing the labor cost for installing new cables. Power cables may have fittings in the tray to maintain clearance between the conductors, but small control wiring is often installed without any intentional spacing between cables. But, such can lead to overheating due to lots of small currents.

Since wires run in conduits or underground cannot dissipate heat as easily as in open air, and adjacent circuits contribute induced currents, wiring regulations give rules to establish the ampacity.

Bus Bars, Bus Duct, Cable Bus

For very heavy currents in electrical apparatus, and for heavy currents distributed through a building, bus bars can be used. Each live conductor of such a system is a rigid piece of copper or aluminum, usually in flat bars (but sometimes as tubing or other shapes). Open bus bars are never used in publicly- accessed areas, but are used in manufacturing plants and power company switch yards to gain the benefit of air cooling. A variation is to use heavy cables, especially where it is desirable to transpose or "roll" phases.

In industrial applications, conductor bars are assembled with insulators in grounded enclosures. This assembly, known as bus duct, can be used for connections to large switchgear or for bringing the main power feed into a building. A form of bus duct known as plug-in bus is used to distribute power down the length of a building; it is constructed to allow tap-off switches or motor controllers to be installed at definite places along the bus. The big advantage of this scheme is the ability to remove or add a branch circuit without removing voltage from the whole duct.

Bus duct may have all phase conductors in the same enclosure (non-isolated bus), or may have each conductor separated by a grounded barrier from the adjacent phases (segregated bus). Likewise, for conducting large currents between devices, cable bus is used. For very large currents in generating stations or substations, where it is difficult to provide circuit protection, isolated-phase bus is used. Each phase of the circuit is run in a separate grounded metal enclosure. A fault in any phase jumps to ground. This type of bus can be rated up to 50,000 amperes and up to hundreds of kilovolts, but is not used for building wiring in the conventional sense.

Electrical Wiring (UK)

The modern UK standards and regulations for electrical wiring no longer differ substantially from those in other European countries. However, there are a number of noteworthy national peculiarities, habits and traditions associated with domestic electrical wiring in the UK (and Ireland) that differ significantly from other countries. Since the electrical wiring principles in TRNC is based on the UK standards it is discussed separately.

- ring circuits
- fused plugs
- switched sockets
- absence of normal switches and sockets in bathrooms (except for special pull-cord ceiling switches and "razor sockets" with built-in isolation transformer)
- historic wiring colors
- asymmetric supply-voltage tolerances

Legal Basis

In England and Wales, the Building Regulations (Approved Document: Part P) require that electrical installations are designed and installed safely according to the "fundamental principles" given in British Standard BS 7671 Chapter 13. These are very similar to the fundamental principles defined in international standard IEC 60364-1 and equivalent national standards in other countries. Accepted ways for fulfilling this legal requirement include

- the rules of the IEE wiring regulations (BS 7671), colloquially referred to as "the regs";
- the rules of an equivalent standard approved by a member of the EEA (e.g., DIN/VDE 0100);
- guidance given in installation manuals that is consistent with BS 7671, such as the IEE On-Site Guide and IEE Guidance Notes No's 1 to 7.

Installations in commercial premises must satisfy in addition various safety legislation, such as the Electricity at Work Regulations 1989. Some works require either building control inspection or must be done by a registered electrician.

Wiring Colors

The standard wiring colors in the UK are (as of 2006) the same as elsewhere in Europe and Australia and follow international standard IEC 60446. This color scheme had already been introduced for appliance flexes in the UK in the early 1970s, however the IEE recommended for fixed wiring until 2006 a different scheme. As a result, the international standard blue/brown scheme is as of 2006 found in all but the oldest appliance flexes. In fixed wiring, the blue/brown scheme is only found in very new (post-2004) installations, and electricians are likely to encounter the old IEE black/red scheme in existing installations for many more decades.

	Pre-2004 IEE	Current IEC
Protective earth (PE)	Green or black	Green/yellow striped
Neutral (N)	Black	Blue
Single phase: Live (L) Three phase: L1	Red	Brown
Three phase: L2	Yellow	Black
Three phase: L3	Blue	Grey

The standard colors in fixed wiring were harmonized in 2004 with the regulations in other European countries and the international IEC 60446 standard. For a transitional period (April 2004 – March 2006) either set of colors were allowed (but not both), provided that any changes in the color scheme are clearly labeled. From April 2006, only the new colors should be used for any new wiring.

The color change has been controversial and was delayed for three decades, because the color blue which was previously used as a phase color is now the color for neutral, and the color black which was previously used for neutral now indicates a phase. While confusion in identification of these conductors could be dangerous, the combination of colors used usually resolves ambiguities. The installation of cables with the 'new' colors in an installation where the 'old' colors exist, could leave the way open for confusion; it is important in such situations that consideration is given to correct identification of the cables – with the use of marker tags if necessary. It has also been suggested that the new phase colors are difficult to distinguish in low-light conditions, but the same can be claimed for most color combinations, including the old British phase colors. A mnemonic advantage of the new colors is that the first two letters of "BLue" and "BRown" match the corresponding positions on the BS 1363 socket face: "bottom left" (neutral) and "bottom right" (live).

Ring Circuits

Ring circuits are commonly used in British wiring with fused 13 A plugs to BS 1363. They are generally wired with 2.5 mm² cable and protected by a 30 A fuse, an older 30 A circuit breaker, or a European harmonized 32 A circuit breaker. Sometimes 4 mm² cable is used if very long cable runs (causing volt drop issues) or derating factors such as thermal insulation are involved. 1.5 mm² Mineral Insulated Copper Clad cable ('pyro') may also be used (as mineral insulated cable can withstand heat more effectively than normal PVC) though obviously more care must be taken with regard to voltage drop on longer runs.

The ring circuit was devised during a time of copper shortage to allow two 3 kW heaters to be used in any two locations and to allow some power to small appliances, and to keep total copper use low. It has stayed the most common circuit configuration in the UK although the 20 A radial (essentially breaking each ring in half and putting the halves on a separate breaker) is becoming more common. Splitting a ring into two 20 A radials can be a useful technique where one leg of the ring is damaged and cannot easily being replaced.

Rules for ring circuits say that the cable rating must be no less than two thirds of the rating of the protective device. This means that the risk of sustained overloading of the cable can be considered minimal. In practice, however, it is extremely uncommon to encounter a ring with a breaker other than 32 A and a cable size other than those mentioned above.

Many lay people in the UK refer to any circuit as a "ring" and the term "lighting ring" is often heard from novices. It is not unheard of to see lighting circuits wired as rings of cable (though usually still with a breaker below the cable rating) in DIY (Do It Yourself) installations.

The IEE Wiring Regulations (BS 7671) permit an unlimited number of socket outlets to be installed on a ring circuit, provided that the floor area served does not exceed 100 m^2. In practice there is normally one ring circuit per storey in a residential installation.

An installation designer may determine by experience and calculation whether additional circuits are required for areas of high demand - for example it is common practice to put kitchens on their own ring circuit or sometimes a ring circuit shared with a utility room to avoid putting a heavy load at one point on the main downstairs ring circuit. A heavy concentration of load close together on a ring circuit is likely to cause overloading of one of the cables unless it is near the middle of the ring.

Infused spurs from a ring wired in the same cable as the ring are allowed to run one single or double socket (the use of two singles was previously allowed but was banned because of people replacing them with doubles) or one fused connection unit (FCU). Spurs may either start from a socket or be joined to the ring cable with a junction box or other approved method of joining cables. Triple and larger sockets are generally fused and therefore can also be placed on a spur.

It is not permitted to have more spurs than sockets on the ring, and it is considered bad practice by most electricians to have spurs in a new installation (some think they are bad practice in all cases).

Where loads other than BS 1363 sockets are connected to a ring circuit or it is desired to place more than one socket for low power equipment on a spur a BS 1363 fused connection unit (FCU) is used. In the case of fixed appliances this will be a switched fused connection unit (SFCU) to provide a point of isolation for the appliance but in other cases such as feeding multiple lighting points (putting lighting on a ring through is generally considered bad practice in new installation but is often done when adding lights to an existing property) or multiple sockets an unswitched one is often preferable.

Fixed appliances with a power rating over 3 kW (for example, electric cookers and showers) or with a non-trivial power demand for long periods (for example, immersion heaters) are not normally connected to a ring circuit but instead are connected to their own dedicated circuit.

One disadvantage of the ring circuit is that it can lead to higher levels of magnetic fields within the rooms served by the ring which can lead to problems with some types of electromagnetic interference such as mains hum and ground loops. Some people claim that these magnetic fields can have undesirable health affects (although this is not generally accepted by the scientific community). These problems can be overcome by encasing the wiring in grounded metal conduit to provide electromagnetic screening.

Ring circuits are not popular outside the UK partly because they are not considered suitable for use with the infused plugs found in most countries.

Installation Accessories

Many accessories for electrical installations (e.g., wall sockets, switches) sold in the UK are designed to fit into the mounting boxes defined in BS 4662, with an 86 mm × 86 mm square face plate that is fixed to the rest of the enclosure by two M3.5 screws (typ. 25 or 40 mm long) located on a horizontal center line, 60.3 mm apart. Double face plates for BS 4662 boxes measure 143 mm × 86 mm and have the two screws 120.6 mm apart.

Where less common accessories (e.g., home-automation control elements from non-UK manufacturers) are installed that are not available in BS 4662 format, other standard mounting boxes may occasionally have to be used, such as those defined in DIN 49073-1 (60 mm diameter, 45 mm deep, fixing screws 60 mm apart) or – less commonly in the UK – ANSI/NEMA OS-1.

The commonly used domestic wall-mount socket used in the UK for currents up to 13 A is defined in BS 1363-2 and normally includes a switch. For higher currents or three-phase supplies, IEC 309 sockets are used instead.

Plug & Accessory Fuses

Some accessories require protection at a lower current than that provided by the ring main protection device. The protection device used in such accessories is a 25 mm ceramic cartridge fuse, rated at 3 A, 5 A, or 13 A.

In the case of permanently connected equipment the fuse is contained in a holder mounted in an accessory known as a fused spur box, which usually includes an isolator switch and often a neon bulb to indicate if the equipment is powered. In this case the fuse protects the spur (equipment supply) cable and any switch contacts.

In the case of non-permanently connected domestic equipment, a socket rated at 13 A is attached to the ring main, into which a fused plug may be inserted. The fuse protects the contacts (including any switch contacts) and the equipment flex. There are two benefits to this arrangement. Firstly with low power equipment a flex with a low current rating (and therefore minimal diameter) can be used. Secondly, if the equipment is moved to a different socket, it will remain protected by the same (hopefully correct) fuse. The disadvantage is that despite warnings to the contrary people often use a fuse rated at too high a current, or even wrap a blown fuse in aluminium foil, meaning that under fault conditions the contacts and flex will be subjected to anything up to the maximum ring main current. This is likely to cause a fire.

Note that the equipment itself should have its own protection measures, such as another fuse, unless the plug or accessory fuse affords all required protection (as is the case with most table lamps, for example).

Consumer Unit

A domestic supply typically consists of a large cable entering the house which is connected to a sealed box containing the main supply fuse. This will typically have a value from 60–100 A. Separate live and neutral cables go from here to a meter, and from there proceed to one or more consumer units. This contains a main switch and individual fuses or Miniature Circuit Breakers (MCBs) for each circuit.

Special locations

Bathrooms

The installation of electrical devices in bathrooms and shower rooms is regulated in Section 601 of BS 7671, and Part B of the Building Regulations. For such rooms, four special zones are defined, in which additional protection is required for electrical facilities:

- Zone 0 is the smallest rectangular volume that contains the bathtub, shower basin, etc.
- Zone 1 is the area above Zone 0, up to a height of 2.25 m above the floor.
- Zone 2 is the area above Zone 1 up to a height of 3 m, as well as the area that is horizontally within 0.6 m from Zone 1.
- Zone 3 is the area above Zone 2 up to a height of 3 m, as well as the area that is horizontally within 2.4 m from Zone 2.

Within Zone 0, only Separated Extra Low Voltage devices are permitted. Any AC transformer supplying such a device must be located outside Zones 0–2. The minimum required ingress protection rating in Zone 0 is IPX7 and IPX4 in Zone 1 and 2. If water jets are likely to occur, at least IPX5 is required in Zone 1–3. Otherwise, in Zone 3 and beyond, an ingress protection rating of IP20 is the minimum required. Equipment in Zone 1–3 must be protected by a 30 mA residual-current circuit breaker (except for shower pumps and shower heaters, where the use of an RCD (Residual Current Device) is so far only recommended).

Shaving sockets (with isolating transformer) are permitted in Zone 2 if direct spray from a shower is unlikely, even if they are only IP20. In a bathroom or shower room, such shaving sockets are the only sockets permitted in the entire room. In any other room with a bathtub or shower, normal sockets are permitted as long as they are outside Zone 3.

Earlier British wiring rules in bathrooms used to be far more restrictive, leading to British peculiarities in bathrooms such as the use of cord switches. The 2001 edition of the Wiring Regulations is more flexible now, placing restrictions on bathroom installations that are now more similar to those in other European countries.

Swimming pools

For swimming pools, Section 603 of BS 7671 defines similar zones. In some of these zones, only industrial sockets according to IEC 60309 are permitted, in order to discourage the use of portable domestic appliances with inappropriate ingress protection rating.

Portable Outdoor Equipment

For use outdoors or in other wet locations (but not bathrooms) special sockets are made. These can be divided into three main groups, industrial sockets which are totally different from the standard sockets, sockets with the same pin out as normal sockets but that will only seal properly when the correct plug and socket are used together (e.g. the 5 A 13 A and 15 A variants of Lewden sockets) and sockets that completely enclose a normal plug with a seal around the flex (e.g. MK master seal).

Sockets that are outside or can "feasibly supply equipment outside the equipotential zone" (a wording that is fairly ambiguous and the exact interpretation of which is subject to some controversy) should be protected by a 30 mA or lower RCD to provide additional safety.

Supply Voltage

For most of the 20th century, the supply voltage in Great Britain in domestic premises has been 240 V AC (rms) at 50 Hz while in Northern Ireland it was 220 V. In 1988, a Europe-wide agreement was reached to change the various national voltages, which ranged at the time from 220 V to 240 V, to a common European standard of 230 V (CENELEC Harmonization Document HD 472 S1:1988).

As a result, the standard nominal supply voltage in domestic single-phase 50 Hz installations in the UK has been 230 V AC (rms) since 1 January 1995 (Electricity Supply Regulations, SI 1994, No. 3021). However, as an interim measure, electricity suppliers can work with an asymmetric voltage tolerance of 230 V +10%/−6% (216.2 V to 253 V). This was supposed to be widened to 230 V ±10% (207 V to 253 V), but the time of this change has been put back repeatedly and currently sits in 2008 (BS 7697). The old standard was 240 V ±6% (225.6 V to 254.4 V), which is mostly contained within the new range, and so in practice suppliers have had no reason to actually change voltages.

The continued deviation in the UK from the harmonized European voltage has been criticized in particular by light bulb manufacturers, who require tighter voltage tolerances to optimize the operating temperature and lifetime of their products, and who currently have to continue producing separate 230 V and 240 V versions.

Electrical Insulation

An insulator is a material or object which contains no free electrons to permit the flow of electricity. When a voltage is placed across an insulator, no charge/current flows.

Explanation

The term *electrical insulator* has the same meaning as the term *dielectric*, but the two terms are often used in different contexts. Conductors and semiconductors, which contain movable charges is the opposite of electrical insulators. Very pure semiconductors are insulators at low temperatures unless doped with impurity atoms that release extra charges which can flow in a current. A few materials (such as silicon dioxide) are almost ideal electrical insulators, a property that is invaluable in flash memory technology. Teflon is another almost ideal insulator, making it a valuable material for long term charge storage in electrets. A much larger class of materials, for example rubber-like polymers and most plastics are still "good enough" to insulate electrical wiring and cables even though they may have lower bulk resistivity. These materials can serve as practical and safe insulators for low to moderate voltages (hundreds, or even thousands, of volts).

Rubber was replaced by polymers in the mid-1960s for premium and heavy duty use.

The main properties of insulation for house wiring are for physical endurance, vs. having good electrical properties. Designers and listers, like UL and CSA, are careful to make the physical properties as good as that of the 1930s and 1940 wires and cables, because they have withstood the test of time. Much wiring of the 1940 vintage is still in use as of 2006.

Physics of Conduction in Solids

Electrical insulation is the absence of electrical conduction. Electronic band theory (a branch of physics) predicts that a charge will flow whenever there are states available into which the electrons in a material can be excited. This allows them to gain energy and thereby move through the conductor (usually a metal). If no such states are available, the material is an insulator.

Most (though not all) insulators are characterized by having a large band gap. This occurs because the "valence" band containing the highest energy electrons is full, and a large energy gap separates this band from the next band above it. There is always some voltage (called, the breakdown voltage) that will give the electrons enough energy to be excited into this band. Once this voltage is exceeded, the material ceases being an insulator, and charge will begin to pass through it. However, dielectric breakdown is usually accompanied by physical or chemical changes that permanently degrade the material's insulating properties.

Materials which lack electron conduction must also lack other mobile charges as well. For example, if a liquid or gas contains ions, then the ions can be made to flow as an electric current, and the material is a conductor. Electrolytes and plasmas contain ions and will act as conductors whether or not electron flow is involved.

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Since 1927, the CSA (Canadian Standards Association) has produced the Canadian *Safety Standard for Electrical Installations*, which is the basis for provincial electrical codes.

Although these two national standards deal with the same physical phenomena and broadly similar objectives, they differ occasionally in technical detail. As part of the NAFTA(The North American Free Trade Area) is the trade block created by the North American Free Trade Agreement (NAFTA) and its two supplements, the North American Agreement on Environmental Cooperation (NAAEC) and the North American Agreement on Labor Cooperation (NAALC) whose members are Canada, Mexico and the United States. It came into effect on 1 January 1994) program, US and Canadian standards are slowly converging towards each other, in a process known as harmonization.

In European countries, an attempt has been made to harmonize national wiring standards in an IEC standard, IEC 60364 *Electrical Installations for Buildings*. However, this standard is not written in such language that it can readily be adapted as a national wiring code. Neither is it designed for field use by electrical tradesmen and inspectors for acceptance of compliance to national wiring standards. National codes, such as the NEC or CSA C22.2, exemplify the common objectives of IEC 60364, and provide rules in a form that allows for guidance of persons installing and inspecting electrical systems.

The 2006 edition of the Canadian electrical code references IEC 60364 and states that the code addresses the fundamental principles of electrical protection in Section 131. The Canadian code reprints Chapter 13 of IEC 60364 and it is interesting to note that there are no numerical criteria listed in that chapter whereby the adequacy of any electrical installation can be assessed.

DKE - German Commission for Electrical, Electronic & Information Technologies of DIN (the German Institute for Standardization) and VDE (German Association for Electrical, Electronic and Information Technologies) - is the German organization responsible for the elaboration of electrical standards and safety specifications.

In the United Kingdom wiring installations are regulated by the produced by the IEE *Requirements for Electrical Installations: IEE Wiring Regulations, BS 7671: 2001* which is now in its 16th edition. The first edition was published in 1882.

Wiring Methods

Materials for wiring interior electrical systems in buildings vary depending on:

- Intended use and amount of power needed of the circuit
- Type of occupancy and size of the building
- National and local regulations
- Environment in which the wiring must operate.

Wiring systems in a single family home or duplex, for example, are simple, with relatively low power requirements, infrequent changes to the building structure and layout, usually with dry, moderate temperature, and no corrosive environmental conditions. In a light commercial environment, more frequent wiring changes can be expected, large apparatus may be installed, and special conditions of heat or moisture may apply. Heavy industries have more demanding wiring requirements, such as very large currents and higher voltages, frequent changes of equipment layout, corrosive, or wet or explosive atmospheres.

Early Wiring Methods

The very first interior power wiring systems used conductors that were bare or covered with cloth, which were secured by staples to the framing of the building or on running boards. Where conductors went through walls, they were protected with cloth tape. Splices were done similarly to telegraph connections, and soldered for security. Underground conductors were insulated with wrappings of cloth tape soaked in pitch, and laid in wooden troughs which were then buried. Such wiring systems were unsatisfactory due to the danger of electrocution and fire, and due to the high labor cost for installation.

Knob & Tube

The earliest standardized method of wiring in buildings, in common use from about 1880 to the 1930s, was *knob and tube* (K&T) wiring: single conductors ran through cavities between the structural in walls and ceilings, with ceramic tubes forming protective channels through joists and ceramic knobs to provide air between the wire and the lumber, and to support the wires.

Other Historical Wiring Methods

Other methods of securing wiring that are now obsolete include:

- Re-use of existing gas pipes for electric lighting. Insulated conductors were pulled into the pipes feeding gas lamps.
- Wood moldings with grooves cut for single conductor wires. These were eventually prohibited in North American electrical codes by the 1930s, but may still be permitted in other regions.

Cables

The first cables for building wiring were introduced in 1922. These were two or more solid copper wires, with rubber insulation, woven cotton cloth for protection of the insulation, then likewise for the overall jacket, usually impregnated with tar as a protection from moisture. Waxed paper was used as fillers and separators. By the 1940s, the labor cost of installing two conductors rather than one cable resulted in a decline in new knob-and-tube installations.

Insulation of these cables was made of rubber. Rubber-insulated cables become brittle over time due to exposure to oxygen, so they must be handled with care, and should be replaced during renovations. When switches, outlets or light fixtures are replaced, the simple act of tightening connections may cause insulation to flake off the conductors. Rubber was hard to separate from bare copper, so copper was tinned.

From the late 1950s, PVC insulation and jackets were introduced, especially for house wiring. About the same time, single conductors with a thinner PVC insulation and a thin nylon jacket became common.

Aluminium wire was common in North American residential wiring from the late 1960s to mid 1970s, due to the rising cost of copper. Due to its greater resistivity, aluminium wiring will typically use one wire gauge larger conductors than would be required of copper - instead of 14 AWG (American wire gauge) for most lighting circuits, aluminium wiring would typically be 12 AWG on a typical 15 amp circuit, though local building codes may vary.

Aluminium conductors were originally used with wiring devices intended for copper wires. Some wiring devices overheated and caused fires. Revised standards for wiring devices were developed to reduce this problem.

Aluminium conductors are still used for power distribution because they cost less than copper wiring, especially in large sizes needed for heavy current loads. Proper installation techniques are required to prevent oxidation and heating of terminations of aluminium conductors.

The simplest form of cable is two insulated conductors twisted together to form a unit; such unjacketed cables with two or three "covered" conductors are used for low-voltage signal and control applications such as doorbell wiring. In North American practice an overhead cable from a transformer on a power pole to a residential electrical service is three twisted (triplexed) wires, often with one being a bare neutral, the other two being "covered" with no voltage rating.

Modern Wiring Materials

Modern nonmetallic sheathed cables (NMC), like (US and Canadian) Type NM, consist of two to four thermoplastic insulated wires and a bare wire for grounding (bonding) surrounded by a flexible plastic jacket.

Rubber-like synthetic polymer insulation is used in industrial cables and power cables installed underground because of its superior moisture resistance.

Insulated cables are rated by their allowable operating voltage and their maximum operating temperature at the conductor surface. A cable may carry multiple usage ratings for applications, for example, one rating for dry installations and another when exposed to moisture or oil.

Generally single conductor building wire in small sizes is solid wire, since the wiring is not required to be very flexible. Building wire conductors larger than #10AWG (or about 6 square millimeters) are stranded for flexibility during installation.

Industrial cables for power and control may contain many insulated conductors in an overall jacket, with helical tape steel or aluminum armor, or steel wire armor, and perhaps as well an overall PVC or lead jacket for protection from moisture and physical damage. Cables intended for very flexible service or in marine applications may be protected by woven bronze wires. Signal cables, such as Ethernet cables, that must be run in air-handling spaces (plenums) of office buildings may be required to be fire-resistant and made with Teflon or other materials that produce little toxic fumes or smoke.

For some industrial uses in steel mills and similar hot environments, no organic material gives satisfactory service. Cables insulated with compressed mica flakes are sometimes used. Another form of high-temperature cable is a mineral insulated cable, with individual conductors placed within a copper tube, and the space filled with magnesium oxide powder. The whole assembly is drawn down to smaller sizes, which compresses the powder. Such cables are fireproof and can be used up to 200 °C, but are costly to purchase and install, and have little flexibility.

Because conductors in a cable cannot dissipate heat as easily as single insulated conductors, they usually are rated at a lower "ampacity". Tables in electrical safety codes give the maximum allowable current for a particular size of conductor, for the voltage and temperature rating of the insulation, and for a given physical environment. The allowable current will be different for wet or dry, for hot (attic) or cool (underground) locations. In a run of cable through several areas, local electrical codes will determine the proper rating of the overall run.

Cables usually are secured by special fittings where they enter electrical apparatus; this may be a simple screw clamp for jacketed cables in a dry location, or a polymer-casketed cable connector that mechanically engages the armor of an armored cable and provides a water-resistant connection. Special cable fittings may be applied to prevent explosive gases from flowing in the interior of jacketed cables, where the cable passes through areas where flammable gases are present. To prevent loosening of the connections of individual conductors of a cable, cables must be supported near their entrance to devices and at regular interval through their length. In tall buildings special designs are required to support the conductors of vertical runs of cable. Usually, only one cable per fitting is allowed. Special cable constructions and termination techniques are required for cables installed in ocean-going vessels; in addition to electrical safety and fire safety, such cables may also be required to be pressure-resistant where they penetrate bulkheads of a ship.

Raceways

Insulated wires may be run in one of several forms of a raceway between electrical devices. This may be a pipe, called a conduit, or in one of several varieties of metal (rigid steel or aluminum) or non-metallic (PVC) tubing. Wires run underground, for example, may be run in plastic tubing encased in concrete, but metal elbows may be used in severe pulls. Wiring in exposed areas, for example factory floors, may be run in cable trays or rectangular raceways having lids. Where wiring, or raceways that hold the wiring traverse fire-resistance rated walls and floors, the openings are required by local building codes to be fire stopped. In cases where the wiring has to be kept operational during an accidental fire, circuit integrity fireproofing must be applied in a bounded manner to comply with the law. The nature and thickness of any passive fire protection materials used in conjunction with wiring and raceways has a quantifiable impact upon the ampacity derating. Special fittings are used for wiring in potentially explosive atmospheres.

Cable trays are used in industrial areas where many insulated cables are run together. Individual cables can exit the tray at any point, simplifying the wiring installation and reducing the labor cost for installing new cables. Power cables may have fittings in the tray to maintain clearance between the conductors, but small control wiring is often installed without any intentional spacing between cables. But, such can lead to overheating due to lots of small currents.

Since wires run in conduits or underground cannot dissipate heat as easily as in open air, and adjacent circuits contribute induced currents, wiring regulations give rules to establish the ampacity.

Bus Bars, Bus Duct, Cable Bus

For very heavy currents in electrical apparatus, and for heavy currents distributed through a building, bus bars can be used. Each live conductor of such a system is a rigid piece of copper or aluminum, usually in flat bars (but sometimes as tubing or other shapes). Open bus bars are never used in publicly- accessed areas, but are used in manufacturing plants and power company switch yards to gain the benefit of air cooling. A variation is to use heavy cables, especially where it is desirable to transpose or "roll" phases.

In industrial applications, conductor bars are assembled with insulators in grounded enclosures. This assembly, known as bus duct, can be used for connections to large switchgear or for bringing the main power feed into a building. A form of bus duct known as plug-in bus is used to distribute power down the length of a building; it is constructed to allow tap-off switches or motor controllers to be installed at definite places along the bus. The big advantage of this scheme is the ability to remove or add a branch circuit without removing voltage from the whole duct.

Bus duct may have all phase conductors in the same enclosure (non-isolated bus), or may have each conductor separated by a grounded barrier from the adjacent phases (segregated bus). Likewise, for conducting large currents between devices, cable bus is used. For very large currents in generating stations or substations, where it is difficult to provide circuit protection, isolated-phase bus is used. Each phase of the circuit is run in a separate grounded metal enclosure. A fault in any phase jumps to ground. This type of bus can be rated up to 50,000 amperes and up to hundreds of kilovolts, but is not used for building wiring in the conventional sense.

Electrical Wiring (UK)

The modern UK standards and regulations for electrical wiring no longer differ substantially from those in other European countries. However, there are a number of noteworthy national peculiarities, habits and traditions associated with domestic electrical wiring in the UK (and Ireland) that differ significantly from other countries. Since the electrical wiring principles in TRNC is based on the UK standards it is discussed separately.

- ring circuits
- fused plugs
- switched sockets
- absence of normal switches and sockets in bathrooms (except for special pull-cord ceiling switches and "razor sockets" with built-in isolation transformer)
- historic wiring colors
- asymmetric supply-voltage tolerances

Legal Basis

In England and Wales, the Building Regulations (Approved Document: Part P) require that electrical installations are designed and installed safely according to the "fundamental principles" given in British Standard BS 7671 Chapter 13. These are very similar to the fundamental principles defined in international standard IEC 60364-1 and equivalent national standards in other countries. Accepted ways for fulfilling this legal requirement include

- the rules of the IEE wiring regulations (BS 7671), colloquially referred to as "the regs";
- the rules of an equivalent standard approved by a member of the EEA (e.g., DIN/VDE 0100);
- guidance given in installation manuals that is consistent with BS 7671, such as the IEE On-Site Guide and IEE Guidance Notes No's 1 to 7.

Installations in commercial premises must satisfy in addition various safety legislation, such as the Electricity at Work Regulations 1989. Some works require either building control inspection or must be done by a registered electrician.

Wiring Colors

The standard wiring colors in the UK are (as of 2006) the same as elsewhere in Europe and Australia and follow international standard IEC 60446. This color scheme had already been introduced for appliance flexes in the UK in the early 1970s, however the IEE recommended for fixed wiring until 2006 a different scheme. As a result, the international standard blue/brown scheme is as of 2006 found in all but the oldest appliance flexes. In fixed wiring, the blue/brown scheme is only found in very new (post-2004) installations, and electricians are likely to encounter the old IEE black/red scheme in existing installations for many more decades.

	Pre-2004 IEE	Current IEC
Protective earth (PE)	Green or black	Green/yellow striped
Neutral (N)	Black	Blue
Single phase: Live (L) Three phase: L1	Red	Brown
Three phase: L2	Yellow	Black
Three phase: L3	Blue	Grey

The standard colors in fixed wiring were harmonized in 2004 with the regulations in other European countries and the international IEC 60446 standard. For a transitional period (April 2004 – March 2006) either set of colors were allowed (but not both), provided that any changes in the color scheme are clearly labeled. From April 2006, only the new colors should be used for any new wiring.

The color change has been controversial and was delayed for three decades, because the color blue which was previously used as a phase color is now the color for neutral, and the color black which was previously used for neutral now indicates a phase. While confusion in identification of these conductors could be dangerous, the combination of colors used usually resolves ambiguities. The installation of cables with the 'new' colors in an installation where the 'old' colors exist, could leave the way open for confusion; it is important in such situations that consideration is given to correct identification of the cables – with the use of marker tags if necessary. It has also been suggested that the new phase colors are difficult to distinguish in low-light conditions, but the same can be claimed for most color combinations, including the old British phase colors. A mnemonic advantage of the new colors is that the first two letters of "BLue" and "BRown" match the corresponding positions on the BS 1363 socket face: "bottom left" (neutral) and "bottom right" (live).

Ring Circuits

Ring circuits are commonly used in British wiring with fused 13 A plugs to BS 1363. They are generally wired with 2.5 mm² cable and protected by a 30 A fuse, an older 30 A circuit breaker, or a European harmonized 32 A circuit breaker. Sometimes 4 mm² cable is used if very long cable runs (causing volt drop issues) or derating factors such as thermal insulation are involved. 1.5 mm² Mineral Insulated Copper Clad cable ('pyro') may also be used (as mineral insulated cable can withstand heat more effectively than normal PVC) though obviously more care must be taken with regard to voltage drop on longer runs.

The ring circuit was devised during a time of copper shortage to allow two 3 kW heaters to be used in any two locations and to allow some power to small appliances, and to keep total copper use low. It has stayed the most common circuit configuration in the UK although the 20 A radial (essentially breaking each ring in half and putting the halves on a separate breaker) is becoming more common. Splitting a ring into two 20 A radials can be a useful technique where one leg of the ring is damaged and cannot easily being replaced.

Rules for ring circuits say that the cable rating must be no less than two thirds of the rating of the protective device. This means that the risk of sustained overloading of the cable can be considered minimal. In practice, however, it is extremely uncommon to encounter a ring with a breaker other than 32 A and a cable size other than those mentioned above.

Many lay people in the UK refer to any circuit as a "ring" and the term "lighting ring" is often heard from novices. It is not unheard of to see lighting circuits wired as rings of cable (though usually still with a breaker below the cable rating) in DIY (Do It Yourself) installations.

The IEE Wiring Regulations (BS 7671) permit an unlimited number of socket outlets to be installed on a ring circuit, provided that the floor area served does not exceed 100 m^2. In practice there is normally one ring circuit per storey in a residential installation.

An installation designer may determine by experience and calculation whether additional circuits are required for areas of high demand - for example it is common practice to put kitchens on their own ring circuit or sometimes a ring circuit shared with a utility room to avoid putting a heavy load at one point on the main downstairs ring circuit. A heavy concentration of load close together on a ring circuit is likely to cause overloading of one of the cables unless it is near the middle of the ring.

Infused spurs from a ring wired in the same cable as the ring are allowed to run one single or double socket (the use of two singles was previously allowed but was banned because of people replacing them with doubles) or one fused connection unit (FCU). Spurs may either start from a socket or be joined to the ring cable with a junction box or other approved method of joining cables. Triple and larger sockets are generally fused and therefore can also be placed on a spur.

It is not permitted to have more spurs than sockets on the ring, and it is considered bad practice by most electricians to have spurs in a new installation (some think they are bad practice in all cases).

Where loads other than BS 1363 sockets are connected to a ring circuit or it is desired to place more than one socket for low power equipment on a spur a BS 1363 fused connection unit (FCU) is used. In the case of fixed appliances this will be a switched fused connection unit (SFCU) to provide a point of isolation for the appliance but in other cases such as feeding multiple lighting points (putting lighting on a ring through is generally considered bad practice in new installation but is often done when adding lights to an existing property) or multiple sockets an unswitched one is often preferable.

Fixed appliances with a power rating over 3 kW (for example, electric cookers and showers) or with a non-trivial power demand for long periods (for example, immersion heaters) are not normally connected to a ring circuit but instead are connected to their own dedicated circuit.

One disadvantage of the ring circuit is that it can lead to higher levels of magnetic fields within the rooms served by the ring which can lead to problems with some types of electromagnetic interference such as mains hum and ground loops. Some people claim that these magnetic fields can have undesirable health affects (although this is not generally accepted by the scientific community). These problems can be overcome by encasing the wiring in grounded metal conduit to provide electromagnetic screening.

Ring circuits are not popular outside the UK partly because they are not considered suitable for use with the infused plugs found in most countries.

Installation Accessories

Many accessories for electrical installations (e.g., wall sockets, switches) sold in the UK are designed to fit into the mounting boxes defined in BS 4662, with an 86 mm × 86 mm square face plate that is fixed to the rest of the enclosure by two M3.5 screws (typ. 25 or 40 mm long) located on a horizontal center line, 60.3 mm apart. Double face plates for BS 4662 boxes measure 143 mm × 86 mm and have the two screws 120.6 mm apart.

Where less common accessories (e.g., home-automation control elements from non-UK manufacturers) are installed that are not available in BS 4662 format, other standard mounting boxes may occasionally have to be used, such as those defined in DIN 49073-1 (60 mm diameter, 45 mm deep, fixing screws 60 mm apart) or – less commonly in the UK – ANSI/NEMA OS-1.

The commonly used domestic wall-mount socket used in the UK for currents up to 13 A is defined in BS 1363-2 and normally includes a switch. For higher currents or three-phase supplies, IEC 309 sockets are used instead.

Plug & Accessory Fuses

Some accessories require protection at a lower current than that provided by the ring main protection device. The protection device used in such accessories is a 25 mm ceramic cartridge fuse, rated at 3 A, 5 A, or 13 A.

In the case of permanently connected equipment the fuse is contained in a holder mounted in an accessory known as a fused spur box, which usually includes an isolator switch and often a neon bulb to indicate if the equipment is powered. In this case the fuse protects the spur (equipment supply) cable and any switch contacts.

In the case of non-permanently connected domestic equipment, a socket rated at 13 A is attached to the ring main, into which a fused plug may be inserted. The fuse protects the contacts (including any switch contacts) and the equipment flex. There are two benefits to this arrangement. Firstly with low power equipment a flex with a low current rating (and therefore minimal diameter) can be used. Secondly, if the equipment is moved to a different socket, it will remain protected by the same (hopefully correct) fuse. The disadvantage is that despite warnings to the contrary people often use a fuse rated at too high a current, or even wrap a blown fuse in aluminium foil, meaning that under fault conditions the contacts and flex will be subjected to anything up to the maximum ring main current. This is likely to cause a fire.

Note that the equipment itself should have its own protection measures, such as another fuse, unless the plug or accessory fuse affords all required protection (as is the case with most table lamps, for example).

Consumer Unit

A domestic supply typically consists of a large cable entering the house which is connected to a sealed box containing the main supply fuse. This will typically have a value from 60–100 A. Separate live and neutral cables go from here to a meter, and from there proceed to one or more consumer units. This contains a main switch and individual fuses or Miniature Circuit Breakers (MCBs) for each circuit.

Special locations

Bathrooms

The installation of electrical devices in bathrooms and shower rooms is regulated in Section 601 of BS 7671, and Part B of the Building Regulations. For such rooms, four special zones are defined, in which additional protection is required for electrical facilities:

- Zone 0 is the smallest rectangular volume that contains the bathtub, shower basin, etc.
- Zone 1 is the area above Zone 0, up to a height of 2.25 m above the floor.
- Zone 2 is the area above Zone 1 up to a height of 3 m, as well as the area that is horizontally within 0.6 m from Zone 1.
- Zone 3 is the area above Zone 2 up to a height of 3 m, as well as the area that is horizontally within 2.4 m from Zone 2.

Within Zone 0, only Separated Extra Low Voltage devices are permitted. Any AC transformer supplying such a device must be located outside Zones 0–2. The minimum required ingress protection rating in Zone 0 is IPX7 and IPX4 in Zone 1 and 2. If water jets are likely to occur, at least IPX5 is required in Zone 1–3. Otherwise, in Zone 3 and beyond, an ingress protection rating of IP20 is the minimum required. Equipment in Zone 1–3 must be protected by a 30 mA residual-current circuit breaker (except for shower pumps and shower heaters, where the use of an RCD (Residual Current Device) is so far only recommended).

Shaving sockets (with isolating transformer) are permitted in Zone 2 if direct spray from a shower is unlikely, even if they are only IP20. In a bathroom or shower room, such shaving sockets are the only sockets permitted in the entire room. In any other room with a bathtub or shower, normal sockets are permitted as long as they are outside Zone 3.

Earlier British wiring rules in bathrooms used to be far more restrictive, leading to British peculiarities in bathrooms such as the use of cord switches. The 2001 edition of the Wiring Regulations is more flexible now, placing restrictions on bathroom installations that are now more similar to those in other European countries.

Swimming pools

For swimming pools, Section 603 of BS 7671 defines similar zones. In some of these zones, only industrial sockets according to IEC 60309 are permitted, in order to discourage the use of portable domestic appliances with inappropriate ingress protection rating.

Portable Outdoor Equipment

For use outdoors or in other wet locations (but not bathrooms) special sockets are made. These can be divided into three main groups, industrial sockets which are totally different from the standard sockets, sockets with the same pin out as normal sockets but that will only seal properly when the correct plug and socket are used together (e.g. the 5 A 13 A and 15 A variants of Lewden sockets) and sockets that completely enclose a normal plug with a seal around the flex (e.g. MK master seal).

Sockets that are outside or can "feasibly supply equipment outside the equipotential zone" (a wording that is fairly ambiguous and the exact interpretation of which is subject to some controversy) should be protected by a 30 mA or lower RCD to provide additional safety.

Supply Voltage

For most of the 20th century, the supply voltage in Great Britain in domestic premises has been 240 V AC (rms) at 50 Hz while in Northern Ireland it was 220 V. In 1988, a Europe-wide agreement was reached to change the various national voltages, which ranged at the time from 220 V to 240 V, to a common European standard of 230 V (CENELEC Harmonization Document HD 472 S1:1988).

As a result, the standard nominal supply voltage in domestic single-phase 50 Hz installations in the UK has been 230 V AC (rms) since 1 January 1995 (Electricity Supply Regulations, SI 1994, No. 3021). However, as an interim measure, electricity suppliers can work with an asymmetric voltage tolerance of 230 V +10%/−6% (216.2 V to 253 V). This was supposed to be widened to 230 V ±10% (207 V to 253 V), but the time of this change has been put back repeatedly and currently sits in 2008 (BS 7697). The old standard was 240 V ±6% (225.6 V to 254.4 V), which is mostly contained within the new range, and so in practice suppliers have had no reason to actually change voltages.

The continued deviation in the UK from the harmonized European voltage has been criticized in particular by light bulb manufacturers, who require tighter voltage tolerances to optimize the operating temperature and lifetime of their products, and who currently have to continue producing separate 230 V and 240 V versions.

Electrical Insulation

An insulator is a material or object which contains no free electrons to permit the flow of electricity. When a voltage is placed across an insulator, no charge/current flows.

Explanation

The term *electrical insulator* has the same meaning as the term *dielectric*, but the two terms are often used in different contexts. Conductors and semiconductors, which contain movable charges is the opposite of electrical insulators. Very pure semiconductors are insulators at low temperatures unless doped with impurity atoms that release extra charges which can flow in a current. A few materials (such as silicon dioxide) are almost ideal electrical insulators, a property that is invaluable in flash memory technology. Teflon is another almost ideal insulator, making it a valuable material for long term charge storage in electrets. A much larger class of materials, for example rubber-like polymers and most plastics are still "good enough" to insulate electrical wiring and cables even though they may have lower bulk resistivity. These materials can serve as practical and safe insulators for low to moderate voltages (hundreds, or even thousands, of volts).

Rubber was replaced by polymers in the mid-1960s for premium and heavy duty use.

The main properties of insulation for house wiring are for physical endurance, vs. having good electrical properties. Designers and listers, like UL and CSA, are careful to make the physical properties as good as that of the 1930s and 1940 wires and cables, because they have withstood the test of time. Much wiring of the 1940 vintage is still in use as of 2006.

Physics of Conduction in Solids

Electrical insulation is the absence of electrical conduction. Electronic band theory (a branch of physics) predicts that a charge will flow whenever there are states available into which the electrons in a material can be excited. This allows them to gain energy and thereby move through the conductor (usually a metal). If no such states are available, the material is an insulator.

Most (though not all) insulators are characterized by having a large band gap. This occurs because the "valence" band containing the highest energy electrons is full, and a large energy gap separates this band from the next band above it. There is always some voltage (called, the breakdown voltage) that will give the electrons enough energy to be excited into this band. Once this voltage is exceeded, the material ceases being an insulator, and charge will begin to pass through it. However, dielectric breakdown is usually accompanied by physical or chemical changes that permanently degrade the material's insulating properties.

Materials which lack electron conduction must also lack other mobile charges as well. For example, if a liquid or gas contains ions, then the ions can be made to flow as an electric current, and the material is a conductor. Electrolytes and plasmas contain ions and will act as conductors whether or not electron flow is involved.

High-Voltage Insulators

High-voltage insulators used for high-voltage power transmission are made from glass, porcelain, or composite polymer materials. Porcelain insulators are made from clay, quartz or alumina and feldspar, and are covered with a smooth glaze to shed dirt. Insulators made from porcelain rich in alumina are used where high mechanical strength is a criterion. Glass insulators were (and in some places still are) used to suspend electrical power lines. Some insulator manufacturers stopped making glass insulators in the late 1960's, switching to various ceramic and, more recently, composite materials.

Recently, some electric utilities have begun converting to composite for some types of insulators which consist of a central rod made of fiber reinforced plastic and an outer weather shed made of silicone rubber or EPDM (ethylene propylene diene monomer rubber). Composite insulators are less costly, lighter weight, and they have excellent hydrophobic capability. This combination makes them ideal for service in polluted areas. However, these materials do not yet have the long-term proven service life of glass and porcelain.

The first glass insulators used in mass had an unthreaded pinhole. These pieces of glass were positioned on a tapered wooden pin, vertically extending upwards from the poles cross arm (commonly only two insulators to a pole and maybe one on top of the pole itself). Natural contraction and expansion of the wires tied to these "thread less insulators" resulted in insulators unseating from their pins, requiring manual reseating.

Amongst the first to produce ceramic insulators were companies in the United Kingdom, with Stiff and Doulton using stoneware from the mid 1840s, Joseph Bourne (later renamed Denby) producing them from around 1860 and Bullers from 1868 Utility patent number. 48,906 were granted to Louis A. Cauvet on 25 July 1865 for a process to produce insulators with a threaded pinhole. To this day, pin-type insulators still have threaded pinholes.

The invention of suspension-type insulators made high-voltage power transmission possible. Pin-type insulators were unsatisfactory over about 40,000 volts.

Insulation of Mast Radiators

In most cases a mast radiator construction requires an insulating mounting; therefore insulators of steatite are used. They have to withstand not only the voltage of the mast radiator to ground, which can reach values up to 400 kV at some mast radiators, but also the weight of the mast construction and dynamic forces. Arcing horns and lightning arresters are necessary because lightning strikes in the mast are common.

At guyed mast radiators (a guy-wire or guy rope is a tensioned cable designed to add stability to tall, narrow structures, frequently radio masts), it is often necessary to use insulators in the guy (if they are not grounded via a coil at the anchor bases), in order to prevent undesired electrical resonances of the guys. These insulators also have to be equipped with over voltage protection equipment. For the dimensions of the guy insulation, static charges on guys have to be considered, at high masts these can be much higher than the voltage caused by the transmitter requiring guys divided by insulators in multiple sections on the highest masts. In this case, guys which are grounded at the anchor basements via a coil - or if possible, directly - are the better choice

Insulation in Electrical Apparatus

The most important insulation material is air, but a wide variety of solid insulators are used in electrical apparatus. In transformers, generators, and electric motors with a maximum of 2500 volts to ground between turns, the insulation on the coil wires is a thin coating of varnish so as to get the maximum number of turns in each slot space. Large power transformer windings are still mostly insulated with paper, wood, and silicone oil; although these materials have been used for more than 100 years, they still provide a good balance of economy and adequate performance. Bus bars and circuit breakers in switchgear may be insulated with glass-reinforced plastic insulation, treated to have low flame spread and to prevent tracking of current across the material. In old apparatus made up to the early 1970's, boards made of compressed asbestos may be used; while this is an adequate insulator at power frequencies, handling or repairs to asbestos material will release dangerous fibers into the air and must be carried out with a high level of precautions. Live-front switchboards up to the early part of the 20th century were made of slate. Electrical power cables may be insulated with polyethylene, cross linked polyethylene, PVC, rubber-like polymers, oil impregnated paper, Teflon, silicone, fluorinate dethylene propylene, modified ethylene terafluor-ethylene, or even compressed inorganic powder, depending on the application.

Insulation materials that perform well at power and low frequencies may be unsatisfactory at radio frequency, due to excess dielectric dissipation.

Low-Voltage Insulating Materials

Flexible insulating materials such as PVC (polyvinyl chloride) is used to insulate the circuit and prevent human contact with a 'live' wire -- one having voltage of 600 volts or less. Alternative materials are likely to become increasingly used due to EU safety and environmental legislation making PVC less economic.

Wires and cables operating at less than 50 volts are "covered" with insulation like materials which are NOT voltage rated: eg: telephone cables, door bell wire, the cables to welding electrodes, the service drop cable from the power company to a building. The main criterion is that of mechanical strength, not electrical.

Class 1 & Class 2 Insulation

Class 1 insulation requires that the metal body of the apparatus/equipment is solidly connected via a "grounding" wire which is earthed at the main Service Panel; but only basic insulation of the conductors is needed. This equipment is easily identified by a round pin for the grounding connection.

Class 2 insulation means that the equipment/apparatus is double insulated and is used on some appliances such as electric shavers, hair dryers and portable power tools. Double insulation requires that the devices have basic and supplementary insulation, each of which is sufficient to prevent electric shock. All internal electrically energized components are totally enclosed within insulated packaging which prevents any contact with "live" parts. They can be recognized because their leads have two pins, or on 3 pin plugs the third (earth) pin is made of plastic rather than metal. In the EU, double insulated appliances all are marked with a symbol of 2 squares, one inside the other.

Collecting Insulators

In the late 1960s and early 1970s, glass insulators were being removed from telephone poles as advances in technology made them obsolete. As linemen were taking down the old lines, they started to notice the multitude of bright colors, company names, variety of shapes, and important historical position held by insulators in the expansion of communication technology. Presently the insulator collecting hobby has thousands of people around the world. A number of websites exist that hold these items as the primary focus, and eBay even has a separate category for insulators.

Collectors have defined a classification system for some of the different styles of small insulators, a price guide (last published in 2003). This is specific to collectors; it is unrecognized, irrelevant and largely unknown by manufacturers. One US-based collector's organization is the National Insulator Association. One magazine in the hobby is a monthly publication, Crown Jewels of the Wire, which has been published since 1969.

Illumination Calculations

Data Tables[1]

Some data used in calculations are given in the tables below.

Table: lm

Lamp Type	Power (W)	lm
fluorescent lamp	40W	2850 lm
fluorescent lamp	20W	1100 lm

Table: η

Reflection: Ceiling	0.80				0.50				0.30	
Wall	0.50		0.30		0.50		0.30		0.50	0.30
Floor	0.30	0.10	0.30	0.10	0.30	0.10	0.30	0.10	0.30	0.10
k = [(a)(b)]/[h(a+b)]	η									
0.60	0.24	0.23	0.18	0.18	0.20	0.19	0.15	0.15	0.12	0.15
0.80	0.31	0.29	0.24	0.23	0.25	0.24	0.20	0.19	0.16	0.17
1.00	0.36	0.33	0.29	0.28	0.29	0.28	0.24	0.23	0.20	0.20
1.25	0.41	0.38	0.34	0.32	0.33	0.31	0.28	0.27	0.24	0.24
1.50	0.45	0.41	0.38	0.36	0.36	0.34	0.32	0.30	0.27	0.26
2.00	0.51	0.46	0.45	0.41	0.41	0.38	0.37	0.35	0.31	0.30
2.50	0.56	0.49	0.50	0.45	0.45	0.41	0.41	0.38	0.35	0.34
3.00	0.59	0.52	0.54	0.48	0.47	0.43	0.43	0.40	0.38	0.36
4.00	0.63	0.55	0.58	0.51	0.50	0.46	0.47	0.44	0.41	0.39
5.00	0.66	0.57	0.62	0.54	0.53	0.48	0.50	0.46	0.44	0.40

Table: E

Room Type	LUX
Car Park	50
Dining Hall	100
Corridor	150
Cafeteria	150
Class/Library	250
Office	250
General Store	250

[1] Chamber of Electrical Engineers, Project Drawing Principles and Help Information book. 5th ed. Nicosia, 2002, pg: 18, 20, 27

Basement

a = 42.5 m

b = 20.7 m

H = 3.1 m

h = H – h1 = 3.1 – 0 = 3.1 m

[2]k = [(a) (b)] / [h (a + b)] = [(42.5) (20.7)] / [3.1 (42.5 + 20.7)] = 4.5

⇨ η = 0.39 (from table)

E = 50 (from table)

2x40W fluorescent lamp

ϕL = (2) (2850) = 5700 lm

d = 1.5

A = (a) (b) = 879.75 m^2

ϕT = (E) (A) (d) / η = (50) (879.75) (1.5) / 0.39 = 169182.7 lm

⇨ n = ϕT / ϕL = 169182.7 / 5700 > 30 pieces of 2x40W fluorescent lamp are going to be used.

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[2] Chamber of Electrical Engineers, Project Drawing Principles and Help Information book. 5^{th} ed. Nicosia, 2002, pg 21

Ground Floor

For stores: 2 ⇨ 7, 10 ⇨ 14

a = 5.5 m

b = 3.0 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(5.5) (3.0)] / [3.15 (5.5 + 3.0)] = 0.62

⇨ η = 0.23 (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 16.5 m^2

ϕT = (E) (A) (d) / η = (250) (16.5) (1.25) / 0.23 = 22418.5 lm

⇨ n = ϕT / ϕL = 22418.5 / 4400 > 6 pieces of 4x20W fluorescent lamp are going to be used.

For stores: 1, 8, 15

a = 5.5 m

b = 4.4 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(5.5) (4.4)] / [3.15 (5.5 + 4.4)] = 0.78

⇨ η = 0.29 (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 24.2 m^2

ϕT = (E) (A) (d) / η = (250) (24.2) (1.25) / 0.29 = 26077.6 lm

⇨ n = ϕT / ϕL = 26077.6 / 4400 > 6 pieces of 4x20W fluorescent lamp are going to be used.

For store: 9

a = 5.5 m

b = 4.95 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(5.5) (4.95)] / [3.15 (5.5 + 4.95)] = 0.83

⇨ η = 0.29 (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 27.225 m^2

ϕT = (E) (A) (d) / η = (250) (27.225) (1.25) / 0.29 = 29337.3 lm

⇨ n = ϕT / ϕL = 29337.3 / 4400 > 6 pieces of 4x20W fluorescent lamp are going to be used.

For store: 16

a = 3.0 m

b = 3.2 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(3.0) (3.2)] / [3.15 (3.0 + 3.2)] = 0.5

⇨ η = 0.23 (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 9.6 m^2

ϕT = (E) (A) (d) / η = (250) (9.6) (1.25) / 0.23 = 13043.5 lm

⇨ n = ϕT / ϕL = 13043.5 / 4400 > 4 pieces of 4x20W fluorescent lamp are going to be used.

For the corridor

a = 3.0 m

b = 28.5 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(3.0) (28.5)] / [3.15 (3.0 + 28.5)] = 0.9

⇨ η = 0.33 (from table)

E = 150 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 85.5 m^2

ϕT = (E) (A) (d) / η = (150) (85.5) (1.25) / 0.33 = 48579.5 lm

⇨ n = ϕT / ϕL = 48579.5 / 4400 > 11 pieces of 4x20W fluorescent lamp are going to be used.

First Floor

For offices: 1 ⇨ 4 & Headmaster's Room

$a = 6.5$ m

$b = 3.0$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(6.5)(3.0)] / [3.15(6.5 + 3.0)] = 0.65$
⇨ $\eta = 0.23$ (from table)

$E = 250$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$

$A = (a)(b) = 19.5m^2$

$\phi T = (E)(A)(d) / \eta = (250)(19.5(1.25) / 0.23 = 26494.6$ lm

⇨ $n = \phi T / \phi L = 26494.6 / 4400 > 6$ pieces of 4x20W fluorescent lamp are going to be used.

For teacher's room: 1, 2 & office 9

a = 5.5 m

b = 3.0 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(5.5) (3.0)] / [3.15 (5.5 + 3.0)] = 0.62

⇨ η = 0.23 (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 16.5 m^2

ϕT = (E) (A) (d) / η = (250) (16.5) (1.25) / 0.23 = 22418.5 lm

⇨ n = ϕT / ϕL = 22418.5 / 4400 > 6 pieces of 4x20W fluorescent lamp are going to be used.

For offices: 5, 7, 8

$a = 5.5$ m

$b = 4.95$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(5.5)(4.95)] / [3.15(5.5 + 4.95)] = 0.83$

⇨ $\eta = 0.29$ (from table)

$E = 250$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$

$A = (a)(b) = 27.225$ m^2

$\phi T = (E)(A)(d) / \eta = (250)(27.225)(1.25) / 0.29 = 29337.3$ lm

⇨ $n = \phi T / \phi L = 29337.3 / 4400 > 6$ pieces of 4x20W fluorescent lamp are going to be used.

For office: 6

$a = 3.0$ m

$b = 3.8$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(3.0)(3.8)] / [3.15(3.0 + 3.8)] = 0.53$

⇨ $\eta = 0.23$ (from table)

$E = 250$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$
$A = (a)(b) = 11.4\ m^2$

$\phi T = (E)(A)(d) / \eta = (250)(11.4)(1.25) / 0.23 = 15489.1$ lm

⇨ $n = \phi T / \phi L = 15489.1 / 4400 > 4$ pieces of 4x20W fluorescent lamp are going to be used.

For the library

$a = 14.2$ m

$b = 4.45$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(14.2)(4.45)] / [3.15(14.2 + 4.45)] = 1.1$

⇨ $\eta = 0.38$ (from table)

$E = 250$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$

$A = (a)(b) = 63.2$ m^2

$\phi T = (E)(A)(d) / \eta = (250)(63.2)(1.25) / 0.38 = 51973.7$ lm

⇨ $n = \phi T / \phi L = 51973.7 / 4400 > 10$ pieces of 4x20W fluorescent lamp are going to be used.

For corridor 1

$a = 2.0$ m

$b = 10.35$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(2.0)(10.35)] / [3.15(2.0 + 10.35)] = 0.53$

⇨ $\eta = 0.23$ (from table)

$E = 150$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$

$A = (a)(b) = 20.7\ m^2$

$\phi T = (E)(A)(d) / \eta = (150)(20.7)(1.25) / 0.23 = 16875$ lm

⇨ $n = \phi T / \phi L = 16875 / 4400 > 4$ pieces of 4x20W fluorescent lamp are going to be used.

For corridor 2

a = 2.0 m

b = 12.15 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(2.0) (12.15)] / [3.15 (2.0 + 12.15)] = 0.55

⇨ η = 0.23 (from table)

E = 150 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 24.3 m^2

ϕT = (E) (A) (d) / η = (150) (24.3) (1.25) / 0.23 = 19809.8 lm

⇨ n = ϕT / ϕL = 19809.8 / 4400 > 5 pieces of 4x20W fluorescent lamp are going to be used.

For Public Relations Department

a = 6.5 m

b = 7.0 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(6.5) (7.0)] / [3.15 (6.5 + 7.0)] = 1.1

⇨ η = 0.33 (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 45.5 m^2

ϕT = (E) (A) (d) / η = (250) (45.5) (1.25) / 0.33 = 43087.1 lm

⇨ n = ϕT / ϕL = 43087.1 / 4400 > 9 pieces of 4x20W fluorescent lamp are going to be used.

Second Floor

For offices: 2 ⇨ 7

$a = 6.6m$

$b = 3.0\ m$

$H = 4.00\ m$

$h = H - h1 = 4.00 - 0.85 = 3.15\ m$

$k = [(a)\ (b)] / [h\ (a + b)] = [(6.6\ (3.0)] / [3.15\ (6.6+ 3.0)] = 0.65$

⇨ $\eta = 0.23$ (from table)

$E = 250$ (from table)

4x20W fluorescent lamp

$\phi L = (4)\ (1100) = 4400$ lm

$d = 1.25$

$A = (a)\ (b) = 19.8\ m^2$

$\phi T = (E)\ (A)\ (d) / \eta = (250)\ (19.8)\ (1.25) / 0.23 = 26902.2$ lm

⇨ $n = \phi T / \phi L = 26902.2 / 4400 > 6$ pieces of 4x20W fluorescent lamp are going to be used.

For offices: 11 ⇨ 16

$a = 5.5$ m

$b = 3.0$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(5.5)(3.0)] / [3.15(5.5 + 3.0)] = 0.62$

⇨ $\eta = 0.23$ (from table)

$E = 250$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$

$A = (a)(b) = 16.5\ m^2$

$\phi T = (E)(A)(d) / \eta = (250)(16.5)(1.25) / 0.23 = 22418.5$ lm

⇨ $n = \phi T / \phi L = 22418.5 / 4400 > 6$ pieces of 4x20W fluorescent lamp are going to be used.

For offices: 8, 17

a = 5.5 m

b = 4.8 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(5.5) (4.8)] / [3.15 (5.5 + 4.8)] = 0.81

⇨ η = 0.29 (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 26.4 m^2

ϕT = (E) (A) (d) / η = (250) (26.4) (1.25) / 0.29 = 28448.3 lm

⇨ n = ϕT / ϕL = 28448.3 / 4400 > 6 pieces of 4x20W fluorescent lamp are going to be used.

For office: 9

$a = 3.0$ m

$b = 3.7$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(3.0)(3.7)] / [3.15(3.0 + 3.7)] = 0.53$

⇨ $\eta = 0.23$ (from table)

$E = 250$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$

$A = (a)(b) = 11.1\ m^2$

$\phi T = (E)(A)(d) / \eta = (250)(11.1)(1.25) / 0.23 = 15081.5$ lm

⇨ $n = \phi T / \phi L = 15081.5 / 4400 > 4$ pieces of 4x20W fluorescent lamp are going to be used.

'or office: 1

= 5.2 m

= 4.3 m

I = 4.00 m

= H – h1 = 4.00 – 0.85 = 3.15 m

= [(a) (b)] / [h (a + b)] = [(5.2) (4.3)] / [3.15 (5.2 + 4.3)] = 0.75

⇨ $\eta = 0.29$ (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 22.36 m^2

ϕT = (E) (A) (d) / η = (250) (22.36) (1.25) / 0.29 = 24094.8 lm

⇨ n = ϕT / ϕL = 24094.8 / 4400 > 6 pieces of 4x20W fluorescent lamp are going to be used.

For the corridor

a = 1.9 m

b = 25.0 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(1.9) (25.0)] / [3.15 (1.9 + 25.0)] = 0.6

⇨ η = 0.23 (from table)

E = 150 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 47.5 m^2

ϕT = (E) (A) (d) / η = (150) (47.5) (1.25) / 0.23 = 38722.8 lm

⇨ n = ϕT / ϕL = 38722.8 / 4400 > 9 pieces of 4x20W fluorescent lamp are going to be used.

Third Floor

For offices: 3, 4

a = 6.5 m

b = 3.0 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(6.5) (3.0)] / [3.15 (6.5 + 3.0)] = 0.65

⇨ η = 0.23 (from table)

E = 250 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 19.5m^2

ϕT = (E) (A) (d) / η = (250) (19.5 (1.25) / 0.23 = 26494.6 lm

⇨ n = ϕT / ϕL = 26494.6 / 4400 > 6 pieces of 4x20W fluorescent lamp are going to be used.

For offices: 1, 2

$a = 5.5$ m

$b = 3.0$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(5.5)(3.0)] / [3.15(5.5 + 3.0)] = 0.62$
⇨ $\eta = 0.23$ (from table)

$E = 250$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$

$A = (a)(b) = 16.5\ m^2$

$\phi T = (E)(A)(d) / \eta = (250)(16.5)(1.25) / 0.23 = 22418.5$ lm

⇨ $n = \phi T / \phi L = 22418.5 / 4400 > 6$ pieces of 4x20W fluorescent lamp are going to be used.

For the cafeteria

a = 10.0 m

b = 9.5 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(10.0) (9.5)] / [3.15 (10.0 + 9.5)] = 1.5

⇨ η = 0.41 (from table)

E = 150 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 95 m^2

ϕT = (E) (A) (d) / η = (150) (95) (1.25) / 0.41 = 43445.1 lm

⇨ n = ϕT / ϕL = 43445.1 / 4400 > 9 pieces of 4x20W fluorescent lamp are going to be used.

For the dining hall

a = 4.1 m

b = 9.35 m

H = 4.00 m

h = H – h1 = 4.00 – 0.85 = 3.15 m

k = [(a) (b)] / [h (a + b)] = [(4.1) (9.35)] / [3.15 (4.1 + 9.35)] = 0.9

⇨ η = 0.33 (from table)

E = 100 (from table)

4x20W fluorescent lamp

ϕL = (4) (1100) = 4400 lm

d = 1.25

A = (a) (b) = 38.3 m^2

ϕT = (E) (A) (d) / η = (100) (38.3) (1.25) / 0.33 = 14507.6 lm

⇨ n = ϕT / ϕL = 14507.6 / 4400 > 3 pieces of 4x20W fluorescent lamp are going to be used.

For the corridor

$a = 2.0$ m

$b = 5.95$ m

$H = 4.00$ m

$h = H - h1 = 4.00 - 0.85 = 3.15$ m

$k = [(a)(b)] / [h(a + b)] = [(2.0)(5.95)] / [3.15(2.0 + 5.95)] = 0.5$

⇨ $\eta = 0.23$ (from table)

$E = 150$ (from table)

4x20W fluorescent lamp

$\phi L = (4)(1100) = 4400$ lm

$d = 1.25$

$A = (a)(b) = 11.9$ m^2

$\phi T = (E)(A)(d) / \eta = (150)(11.9)(1.25) / 0.23 = 9701.1$ lm

⇨ $n = \phi T / \phi L = 16769 / 4400 > 3$ pieces of 4x20W fluorescent lamp are going to be used.

Conclusion

To conclude all the info given in the report,

An engineer has to know all the little details about, insulation, wiring methods, llumination needs, cable types, the work that is desired to be done in the place that the lectrical system is and respective calculations.

Knowing all this will grant the engineer focus over creating a stable, satisfying and the nost suitable electrical system to the desired place.

Thus this project showed us how the work is done over a big building that has a car ark, offices, stores, eatery and education places.

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