

APPARATUS FOR THE SUPPRESSION OF RADIO INTERFERENCE

Methods of Connecting Suppression Capacitors

1. Scope of Instruction. This Instruction describes the methods of connecting capacitors to electrical supply systems and appliances. It deals with the safety precautions which must be observed, and in particular with the prevention of shock and the limitation of earth-leakage currents.

2. General. The fitting and wiring of suppression apparatus should be carried out strictly in accordance with the regulations of the local Area Board of the British Electricity Authority. Such regulations are usually based on, and differ very little from, the "Regulations for the Electrical Equipment of Buildings" issued by the Institution of Electrical Engineers. Radio interference suppression apparatus should comply with the current edition of B.S. 613 "Components for Radio Interference Suppression Devices". If the suppressor is not to be fitted by an investigation officer, the installer should be advised of any relevant regulations that should be observed.

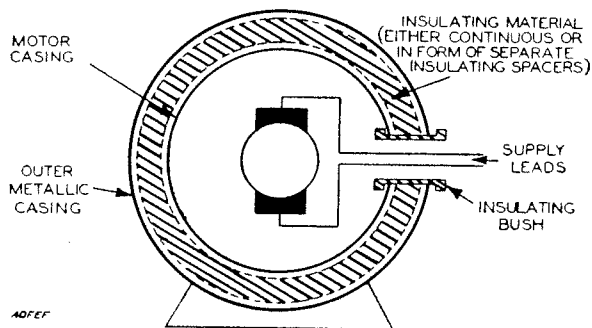


FIG. 1—A DOUBLE-INSULATED APPLIANCE

3. Definition of terms.

(a) *Appliance, all-insulated.* An appliance having a wholly insulating case and no accessible conducting parts.

(b) *Appliance, double-insulated (see Fig. 1).* An appliance, partially or wholly metal clad, having adequate spacing or suitable insulating material not only between every live part and its surrounding envelope (if a cable) or immediate support (if bare), but also between the envelope or support and an external casing which so encloses the complete appliance that no internal part can be touched. It is not intended that the outer metalwork of a double-insulated appliance should be earthed.

(c) *Earthed.* Electrically connected to the general mass of earth by means of an earth electrode.

(d) *Earth electrode.* A metal rod, water-pipe or other conductor electrically connected with the general mass of earth.

(e) *Earth continuity conductor.* The wire, clamp, or other conductor, connecting to the earthing lead and to each other those parts of an installation which are required to be earthed. It may be in whole or part the metal conduit or the metal sheath of the cables, or the special continuity wire of a cable or flexible cord incorporating such a wire.

(f) *Permanently earthed.* An appliance of which the exposed metal is connected to an earth electrode by conduit, metal cable-sheath, supply continuity conductor or other permissible method, rigidly and permanently secured throughout its whole length and protected from mechanical damage and corrosion, unless by its nature and construction it is so protected. In addition, there shall be no fuse, switch, circuit-breaker, resistor or reactor in the earth connexion.

NOTE:—Appliances earthed through two-pole and earthing-pin plug and socket connexions cannot be regarded as permanently earthed.

(g) *Earth-free situation.* One in which there is no earthed metalwork accessible to the touch.

NOTE:—Bathrooms, sculleries, damp situations and rooms with concrete floors are not deemed to be earth free.

PERMISSIBLE CAPACITANCE VALUES

4. The maximum values of capacitance which may be connected to the mains and appliances are given in Table 1. The reasons for specifying these values are given in paragraphs 5 to 17 and standard practical methods of connecting the capacitors are discussed in paragraphs 18 to 35.

5. Risk of shock. It is a statutory requirement that an electricity distribution network shall be earthed at one point, normally the power-station or transforming-station. Because of this, the connexion of a capacitor from an electric main to exposed metal which is not earthed would cause an electric current to pass through the body of a person who was simultaneously in contact with the metalwork and earth. With a D.C. supply the current would be a momentary one arising from the charge of the capacitor. With an A.C. supply, the current would be maintained. It is possible to restrict the value of the capacitance so that while the capacitor is not rendered useless as a suppressor, the current through the person's body would be limited to so low a value that no sensation of shock would be felt. Differing values would apply to A.C. and D.C. systems, but any capacitors installed in 'Universal' (A.C./D.C.) appliances would have to conform to the more stringent limitation, i.e. the A.C. case.

6. The potential difference between a "live" main and earth may be as much as 250 V. + 6%, whereas the potential difference between a "neutral" main and earth will seldom or never exceed 15 to 20 volts. If therefore the polarity (i.e. "live" or "neutral") of each lead to an electrical apparatus could be determined and maintained indefinitely, differing maximum permissible values of capacitance could be specified for connexion between each main and earth. Unfortunately there are risks that in service the two mains may become changed-over, e.g. two-pin plugs are reversible, and for some classes of apparatus it is therefore necessary to treat both conductors as possible "live" mains. Risk of shock with large values of capacitance connected to exposed metalwork could be eliminated if permanent earth connexions could be provided, but for many applications there is a considerable chance of the earth connexion being omitted during installation or, if provided, of it becoming disconnected in service. It was by bearing in mind such possibilities that the maximum permissible values laid down in Table 1 were arrived at; the table is, in fact, based on B.S. 613.

7. An appliance that is not permanently earthed should have the values of capacitance from both mains limited, owing to the possibility of the earth connexion being broken. With a permanently earthed appliance it is still necessary to limit the value of capacitance from the "live" main to frame because of the possibility of an earthing failure. The permanent nature of the wiring makes it unlikely however that the mains connexions will be interchanged at the same time as an earthing fault occurs, and it is therefore possible to allow a larger capacitance between the "neutral" main and frame.

8. **Plug Suppressors.** If capacitors are fitted in a three-pin plug it is possible to use a larger-value capacitance between the "neutral" main and frame [see Table 1, Item (b)] than if it had been fitted at the appliance, since there is less likelihood of the "neutral" and "live" mains being reversed. The maximum value of capacitance permissible between lines is limited because of the possibility of the capacitor holding a charge if the switch on the appliance is in the 'off' position when the plug is withdrawn from a live socket. For special precautions to be observed when using plug suppressors see par. 35.

9. **Insulated appliances.** For *all-insulated appliances* the maximum value of capacitance which may be connected to the frame of the machine need only be limited by its effectiveness as a suppressor. For *double-insulated appliances* the value of capacitance connected between each main and the *inner* frame is limited, since a capacitor so connected reduces the effective insulation of the appliance. On no account may capacitors be connected to the exposed metalwork of a double-insulated appliance.

10. **Earth-leakage currents.** The connexion of a capacitor between an A.C. supply and earth will result in an earth-leakage current flowing, the magni-

tude of the current depending on the impedance in circuit and the impressed voltage. This only becomes a problem with permanently-earthed appliances used on A.C. supplies, where comparatively large values of capacitances could be connected from the neutral main to the frame and earth. The voltage impressed on a capacitor connected from the neutral main to earth will seldom exceed 15-20 volts.

11. If an earth-leakage or differential circuit-breaker is used to protect a sub-circuit supplying one or more appliances, the earth-leakage capacitance current has to be limited to a value at which there will be no risk of false operation of the circuit-breaker. If suppression capacitors are fitted to such an installation, a check must be made to ensure that their presence does not cause operation of the safety device. If it does, the total capacitance connected to earth must be reduced until the circuit-breaker no longer operates. Earth-leakage current is also limited by the requirements of the I.E.E. "Regulations for the Electrical Equipment of Buildings" and the Electricity Supply Regulations. Capacitance connected from the live and neutral mains to earth should therefore be limited as indicated in Table 1, Item (c) which applies to the standard 50 c/s. 250-volt system, the neutral main being earthed at the supply station.

12. **Other safety precautions.** Whilst most of the shock and earth-leakage precautions may be regarded as matters of safety, additional care is necessary if the connexion of a suppressor may affect the proper functioning of the apparatus. For example, if capacitors are fitted indiscriminately on a lift installation the operation of contactors and relays controlling safety devices, such as door interlocks, may be affected, and the installation rendered dangerous by incorrect operation of such devices.

13. Apparatus in which the sequence of operation of contactors is important may be seriously affected if the operation of some of the contactors is delayed by the action of the capacitor. The application of suppressors to highly specialized apparatus should not therefore be undertaken without the co-operation of the manufacturer.

14. A simple device such as an electric smoothing-iron or bed-warmer may be made a potential cause of fire if the thermostatic control is adversely affected by incorrectly fitting a suppressor.

15. *If inductors are used in addition to capacitors* the total impedance introduced in circuit should not be such as to limit the current to such an extent that the operation of circuit protective devices, e.g. fuses would be prevented.

16. **Connexion of capacitors to machine frames.** The "earth" connexion of a capacitor filter should be made to the frame of an appliance and not to a separate earth. Capacitors must not be connected to the exposed metalwork of a double-insulated appliance but to the inner framework.

17. The I.E.E. "Regulations for the Electrical Equipment of Buildings" dealing with earthing advise that "all exposed metalwork other than current-carrying parts . . . shall be earthed". Exemptions are metalwork in earth-free situations [see par. 3 (g)], short isolated lengths of conduit and metalwork of extra-low-voltage circuits (i.e. not exceeding 30 volts r.m.s. A.C. or 50 volts D.C.). The latter exemption may not apply in premises subject to the Factories Acts.

PRACTICAL METHODS OF CONNECTING CAPACITORS TO SUPPLY SYSTEMS AND PERMANENTLY-EARTHED APPLIANCES

18. The practical methods of connecting capacitors to supply systems and permanently-earthed appliances are shown in Figs. 2, 3, 4 and 5, and are dealt with in the following paragraphs. For the purpose of illustration the capacitors in these figures are represented by "Filters, Suppression, No. 24" (which will eventually replace "Units, Capacitor, No. 7Y"). This filter consists of two Group II capacitors, rated at 250 V. A.C., in a single container of moulded material. Fuses are incorporated and the terminals are marked E (earth), N (neutral), and L (live). "Filter, Suppression, No. 23" is similar, with the exception that fuses are not fitted. Capacitors for the two recognised circuit positions should comply with the current edition of B.S. 613 (see E 0010).

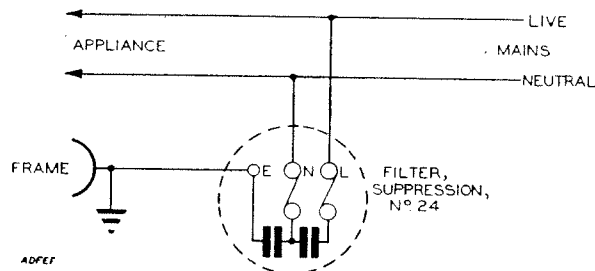


FIG. 2—METHOD OF CONNECTING CAPACITORS TO A.C. OR D.C. PERMANENTLY EARTHED APPLIANCES

19. **2-wire D.C. or A.C. systems.** In these systems, one conductor is normally earthed at the supply station or sub-station. One conductor is therefore 'neutral' (i.e. approximately at earth potential) and the other line 'live'. Capacitors for appliances supplied from these systems are connected as shown in Fig. 2.

20. **3-wire D.C. system.** This system utilises three conductors, the 'positive outer', 'neutral', and 'negative outer', as shown in Fig. 3. The neutral is earthed at the supply station, and a voltage V is maintained between each outer and neutral. The voltage between the outers is $2V$. The method of connecting "Filters, Suppression, No. 24" to this system is shown in Fig. 3.

21. For lighting and small-power purposes, one outer and the neutral are led into the consumer's premises. This arrangement may be regarded as a 2-wire D.C. supply and the capacitors may be connected to appliances as shown in Fig. 2.

22. Large machines are commonly supplied from the outers at the double voltage and Group II capacitors of suitable voltage rating may be connected as in Fig. 2.

23. **3-wire, 3-phase system.** This system utilises three conductors, none of which is earthed, carrying voltages 120 degrees out of phase with each other. This system is used for supplying 3-phase motors and

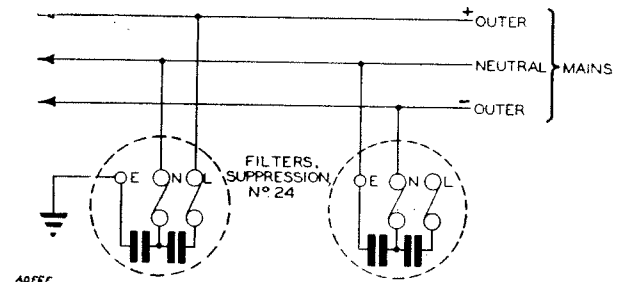


FIG. 3—METHOD OF CONNECTING CAPACITORS TO 3-WIRE D.C. SUPPLY SYSTEM

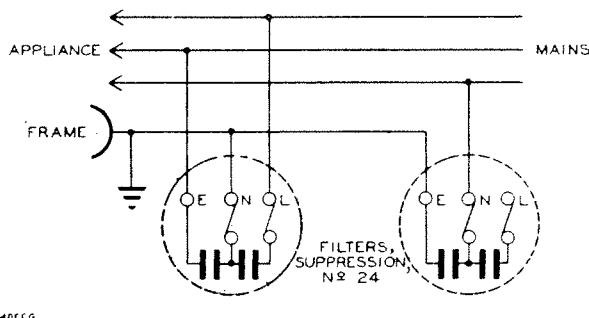


FIG. 4—METHOD OF CONNECTING CAPACITORS TO 3-WIRE 3-PHASE PERMANENTLY EARTHED APPLIANCES

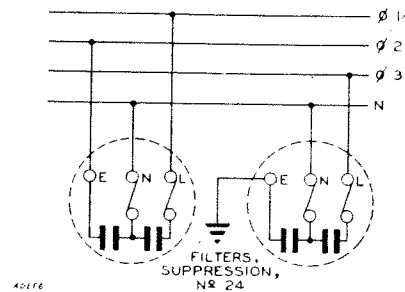


FIG. 5—METHOD OF CONNECTING CAPACITORS TO A 4-WIRE 3-PHASE SUPPLY SYSTEM

other loads, provided the load currents in all conductors are balanced. The method of connecting capacitors to appliances supplied from this system is shown in Fig. 4.

24. 4-wire, 3-phase system. This system utilises three line conductors and a neutral which is earthed at the sub-station. Voltages V , displaced in phase by 120 degrees, are maintained between each line conductor and neutral, and the voltage between any pair of line conductors is $\sqrt{3}V$. The rated voltage of such a system is the voltage between each line and neutral; this is known as the 'line' voltage, whilst the voltage between two line conductors is known as the 'phase' voltage.

25. For lighting and small-power purposes (i.e. domestic appliances and fractional-H.P. motors), one line conductor and the neutral are led into the consumer's premises; this arrangement may be regarded as a 2-wire A.C. supply and capacitors may be connected as shown in Fig. 2.

26. For mercury-arc rectifiers or 3-phase motors, all four wires, or in some cases only three line wires (see par. 23), are led in. Two "Filters, Suppression, No. 24" may be connected as in Fig. 5.

27. Medium-voltage and high-voltage circuits. For circuits having voltages exceeding 250 V., capacitors of high-working-voltage suitable for test purposes, e.g. on mercury-arc plant, are available in small quantities. Applications for loan should be made to the Eng. Dept. (WP2/3). Particulars of the installation should accompany the loan requisition. It is not permissible to connect two low-voltage capacitors in series to increase their working voltage.

PRACTICAL METHODS OF CONNECTING CAPACITORS TO APPLIANCES NOT PERMANENTLY EARTHED

28. Portable appliances. To comply with the earthing requirements of the I.E.E. "Regulations for the Electrical Equipment of Buildings" (see par. 17), portable appliances are often fitted with a three-core flexible cord and an appropriate plug for insertion in a three-pin socket-outlet; the third wire provides the earth connexion to the frame of the appliance. Appliances earthed in this way are not regarded as permanently earthed.

29. The majority of appliances not permanently earthed are of the portable type, but there are some

non-portable appliances, e.g. refrigerators, which do not always have a permanent earth-connexion.

30. Capacitor filters. Fig. 6 shows the method of connecting capacitors to an appliance which is not permanently earthed. The maximum values of capacitance which may be used are given in Table 1, Items (a) and (d).

31. "Units, Capacitor No. 8A" are designed for use with appliances which are not permanently earthed and consist of two $0.005\mu\text{F}$. Group I capacitors and one $0.1\mu\text{F}$. Group II capacitor rated at 250 V. A.C. in a single container. They are intended for fitting inside an appliance which is rated for use on 250-V. 50 c/s. supplies and which has exposed metal work not permanently earthed; the casing of the appliance providing mechanical protection for the unit.

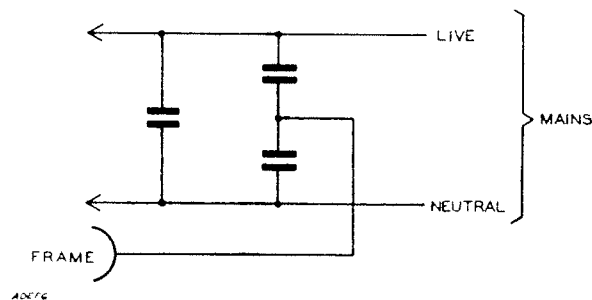


FIG. 6—METHOD OF CONNECTING CAPACITORS TO AN APPLIANCE NOT PERMANENTLY EARTHED (FOR MAXIMUM CAPACITANCE VALUES SEE TABLE 1)

32. "Units, Capacitor No. 9A" use the same capacitors as "Units, Capacitor No. 8A" but they are enclosed in a moulded case and can be fitted in the flexible lead to the appliance.

33. With appliances not permanently earthed the small value of capacitance ($0.005\mu\text{F}$.) which may be connected from each line to frame may not give adequate suppression. For these appliances, it is usually necessary to insert series inductors to supplement the action of the capacitors. Alternative arrangements to avoid the need to use inductors would be the use of mains-plug suppressors [see Table 1, Item (b) and Fig. 7] or capacitors at the socket-outlet. For the latter arrangement the capacitance limitations for permanently earthed appliances would apply [see Table 1, Item (c)].

TABLE 1.—MAXIMUM VALUES OF CAPACITANCE WHICH MAY BE CONNECTED TO AN APPLIANCE OR TO THE SUPPLY MAINS

Location of suppressor	Rating of appliance	Maximum capacitance in $\mu\text{F.}$ which may be connected from			For practical method of connexion see Fig.
		Live main to exposed metalwork or earth continuity conductor (inner framework only for double-insulated appliance)	Neutral main to exposed metalwork or earth continuity conductor (inner framework only for double-insulated appliance)	Live main to neutral	
(a) In or on an appliance (not double-insulated) which is not permanently earthed or in the flex lead thereof	A.C. or A.C./D.C., not exceeding 250 V.	0.005	0.005	2.0	6
	D.C. only, not exceeding 250 V.	0.1	0.1	2.0	6
(b) In the 3-pin plug of an appliance (not double-insulated) which is not permanently earthed	A.C. or D.C., not exceeding 250 V.	0.005	0.05	0.1	7 (b)
(c) Associated with permanently earthed installations	250 V. A.C., single phase	0.005†	1.0	2.0	2
	A.C., 3-phase, not exceeding 500 V. between phases	2.0‡	2.0‡	2.0‡	4, 5
	250 V. D.C.	0.1	2.0	2.0	2
(d) In or on a double-insulated appliance	A.C. or D.C., not exceeding 250 V.	0.05§	0.05§	2.0	—
(e) In or on an all-insulated appliance	A.C. or D.C., not exceeding 250 V.	No limit from point-of-view of safety		2.0	—

NOTES:

† If necessary to secure adequate suppression, this limit may be relaxed, subject to the approval of the Electricity Authority and of any other authority concerned [e.g. Ministry of Labour and National Service (Factory Dept.)].

‡ Conditional upon all the capacitors connected between phases and frame being of the same nominal value, and upon the supply circuit being so protected by a circuit-breaker that all phases are disconnected simultaneously. If the neutral is available, the capacitors should be connected from the phase wires to the neutral, and a $2\mu\text{F.}$ capacitor should be connected from the neutral to the frame or earth continuity conductor.

§ Capacitors must not be connected to the exposed metalwork of a double-insulated appliance.

34. In some cases, e.g. refrigerators, washing machines, etc., it may be much simpler to provide a permanently-earthed connexion to the frame of the machine so that larger value capacitors may be used.

35. *Precautions to be observed when using mains-plug suppressors or fitting capacitors to socket-outlets.*—It is

essential to ensure that the socket-outlet is wired in accordance with Fig. 7(a) and that the earth-socket is connected to earth. When using mains-plug suppressors, all the socket-outlets at which the appliance may be used should be checked for correct wiring and for the presence of an efficient earth connexion.

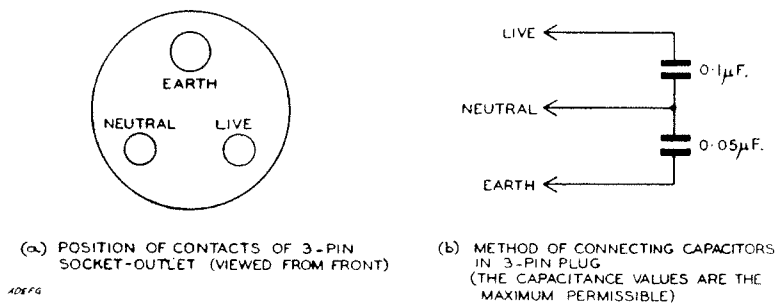


FIG. 7—PLUG SUPPRESSOR

Reference :—E 0010

(WP2/3)

Instruction cancelled :—General, C 0322

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