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POST OFFICE ELECTRICAL ENGINEERS

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Col. A. S. ANGWIN,
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## A PAPER

*Read before the South Lancs. Centre of the Institution on the 1st March, 1932, and before the North Ireland Centre on the 12th April, 1932.*

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# INTERFERENCE WITH WIRELESS RECEPTION ARISING FROM THE OPERATION OF ELECTRICAL PLANT.


## SUMMARY.

Ascribes the present day interference problem to the improvement in modern receiver design and the greatly increased use of industrial plant of all descriptions. Briefly refers to the organisation existing in this country and to the attitude adopted in other countries in dealing with the problem. Mentions the high frequency and low frequency causes of interference, and in regard thereto gives data relative to the high frequency characteristics of supply mains, the low frequency harmonic content of alternating current supplies and low frequency ripple and its smoothing. Describes the general method adopted in tracing sources of interference and details the important types of interfering plant met with to date. Gives methods of curing high frequency interference at listeners' premises and discusses the question of remedies applied at the source and at the radio receiver. Deals in conclusion with the problems of the future and refers to interference from high tension transmission lines and also from aeroplanes and motor cars.


## INTRODUCTION.

In recent years progress in design has led to the production of wireless receivers with much greater sensitivity than has been possible hitherto, consistent with good quality of reproduction. This increased amplification in receivers has naturally accentuated the problem of interference.

The use of mains-operated receivers has also had a marked effect in bringing the question of interference into prominence, as such receivers are more liable to interference owing to their connection to the electric mains which are conveyors of electrical disturbances.

The progressive adoption of electricity for industrial and domestic purposes has also increased the difficulties. Many items of electrical equipment as at present designed are potential sources of disturbance to radio reception, and the number of cases of interference tend therefore to increase as new electrical plant is installed.

The general problem of interference caused by electrical plant is not a new one. Prior to the introduction of Broadcasting it was however only necessary to consider it in relation to commercial receiving stations and in such cases by a suitable choice of site and special attention to the design of plant the reduction of interference to reasonable proportions was possible. In the case of broadcast reception, however, the site is fixed and of limited dimensions whilst the design of the apparatus is restricted both by the question of cost and by the available accommodation. Attention has therefore to be directed to the possibility of eliminating the interference at the source and this, as a general rule, is the ideal solution to be aimed at.

Where this cannot be attained, palliatives are usually possible, but, at its worst, interference propagated from electrical machinery may be of such a high acoustic level at the output of the receiver as to completely spoil broadcast reception.

## TREATMENT OF INTERFERENCE CASES.

In this country every broadcast listener pays (or should pay) an annual licence fee for the right to instal and operate wireless receiving apparatus and expects to be able to receive a broadcast programme unaccompanied by annoying disturbances. The British Broadcasting Corporation and the Post Office have made a practice of assisting as far as possible in the elimination of interference from avoidable causes and have paid special attention to this particular aspect of the general problem of radio interference.

This involves a great deal of investigation and research both in regard to the number of individual cases dealt with and the determination of solutions applicable to particular types of radio interference.

Before the investigations are undertaken, however, the complainants are invited to complete and return a questionnaire which often furnishes sufficient information as to the nature of the interference complained of.

Complaints are received both by the B.B.C. and the Post Office and all receive the attention of the Post Office, being dealt with either by the local P.O. Engineering staff or in special cases by the Engineer-in-Chief's Headquarter staff.

As an indication of the extent of the work it is of interest to note that the total number of cases of electrical interference dealt with per annum is at present approximately 10,000, of which 3,000 are received by the B.B.C. and forwarded to the Post Office for attention. Investigation of these cases involves various tests and the subsequent fitting, on an experimental basis in the first instance, of remedial apparatus, enabling a demonstration of cures to be given to complainants and owners of offending plant. A general description of the method adopted in tracing sources of interference is given later in the paper.

The permanent fitting of the remedial apparatus is then usually a question for amicable settlement between the parties concerned.

As a general rule it has been found that owners of offending plant are willing to co-operate in the suppression of interference. Exceptional cases do, of course, arise where a practicable and effective remedy is not applied owing to the creation of an impasse.

It may be of interest to note the position and procedure adopted or recommended for adoption by other countries in dealing with broadcast interference. The following paragraphs summarise the views which have been expressed at meetings of the C.C.I.R.* when consideration has been given to the subject of the desirability of administrations enacting laws prohibiting or limiting such interference.

In most countries the view is held that interference from industrial plant should be eliminated at the source, although at the same time in certain countries, notably Germany, Italy, Norway, Holland, Great Britain and Switzerland, it is considered that very effective steps to meet the difficulties in some measure can be undertaken at the receiving station.

In regard to the question of the effects produced on the normal working of industrial plant by the fitting of remedial apparatus, it is generally agreed that the efficiency of such plant is not thereby impaired, although in certain instances further research is required before completely satisfactory non-interfering plant can be supplied.

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* Comité Consultatif International technique des Communications Radioléctriques.

The conditions vary in different countries as to the powers available to enforce legal action against users of electrical plant producing interference.

In some countries legal action is resorted to where necessary, other countries propose legislation and the question has been raised of the necessity for international agreement to ensure that interference of this nature shall not be propagated beyond the national territory where the disturbance arises.

The certification of machinery as regards freedom from causing interference would considerably simplify the interference problem as it exists to-day. It is an ideal to be striven for and would require international agreement for it to be entirely effective. Many difficulties stand in the way of its attainment and although the idea is favoured in a number of countries, notably in Germany, Spain, Norway, Switzerland and the Union of Socialistic Soviet Republics, it is at the moment thought to be impracticable. One of the matters immediately arising from its enforcement is the prohibition of the import and export of non-certified plant, and this is generally agreed to present an almost insuperable bar to the scheme.

## CAUSES OF INTERFERENCE AND ITS PROPAGATION.

The experience of the British Post Office in dealing with interference from all types of electrical plant has covered a very wide ground.

Under the system of investigation which has been employed for several years, the procedure for dealing with all cases presenting difficulty or revealing unusual features is centralized in the Radio Section of the Engineering Headquarters in London. The organization provides that all complaints reach that Office after investigations have been made, and the information collected in this way together with the results of a number of special investigations has led to the gradual accumulation of knowledge of the causes of interference and the means of limiting its effects on reception.

### *High Frequency Interference.*

Most interference is of a high-frequency nature and is attributable to the sudden changes of current in electrical circuits, *e.g.*, the making and breaking of operating devices, contactors, keys, etc., to the use of spark gaps and to imperfect contacts in switches, etc. These sudden changes of current cause the potential of some part of the circuit wiring to change rapidly, at frequencies within the broadcast bands. The wiring then behaves as a transmitting aerial, and high frequency waves are radiated which may be picked up by the aerial of the receiver and/or its associated apparatus. Interference propagated in this way from the disturbing plant and its associated cabling is referred to as "direct radiation" and accounts for only a relatively small proportion, say 10%, of the complaints due to high frequency interference.

A more frequent source of trouble to which 90% of the cases of H.F. interference are attributable arises from the direct conduction of H.F. currents, *via* the supply mains to the internal wiring of listeners' premises. The high frequency potential imposed on house wiring in this way, may be only a few microvolts, but as the wireless aerial and lead-in are in close proximity to the wiring, the interference experienced can be as strong as the signal received from a 50 k.w. transmitter situated say 30 miles away.

All remedies for high-frequency interference are based upon the following considerations:—

1. The reduction to negligible proportions of the H.F. voltages impressed on those sections of the mains or wiring which are capable of radiating interference.
2. The restriction of the H.F. voltages to as small a section of the supply mains as possible, or to wiring which is remote from the listener's receiver. It is sometimes necessary to apply both the above principles to effect substantial improvement in reception.

The received field strength from a transmitting station is decreased by a decrease of aerial current, by a decrease of effective aerial height of transmitter or receiver and by an increase of the distance between the transmitter and the receiver. For similar reasons the effect of an interfering source is reduced by decreasing the intensity of the propagated H.F. currents, by a lower effective height of the receiving aerial and by increasing the distance between the receiver, with its aerial, and the interfering source, *e.g.*, the house-wiring.

The production of high frequency interference in the case of industrial machinery is sometimes considered to be chiefly associated with " sparking " such as is experienced at the brushes of a badly maintained generator. Although disturbances are at times accompanied by sparking it cannot be assumed that because a machine is not sparking no interference with reception can arise. The conditions in the case of a motor may indeed be exactly contrary and investigations have shown that a motor running with the brushes in the correct position and with no apparent sparking may produce considerable interference. In such a case it has been observed that by rotation of the brushes a position can be found where the interference is considerably reduced, the sparking however may then be so excessive as to preclude the continuous running of the machine.

*The Electrical Characteristics of Supply Mains at Broadcast Frequencies.*

The electrical characteristics of supply mains have an influence on the propagation of H.F. currents and the curing of the resulting interference.

The radio frequency currents do not flow around the mains but circulate outward from the source along both mains, returning through the capacity of the mains and connected equipment to earth. The impedance to earth of the mains is of importance in this connection.

Some preliminary tests of these characteristics as measured at listeners' premises are shown in the curves given in Fig. 1. It will be observed that the reactance at radio frequency of the path between mains and earth may be either inductive or capacitative, and that its actual value may vary from zero to very high values indeed.

The curves explain a number of phenomena which have been observed from time to time. For example, it has often been found that interference is practically confined to one particular frequency and that it is extremely difficult to effect a cure. In such cases the impedance of the mains to earth may be so low that the addition of earthed condensers does not shunt any appreciable proportion of the H.F. currents.

As to whether the mains impedance is inductive or capacitative, will doubtless depend very largely on the nature of nearby plant connected to such mains. Thus electrical

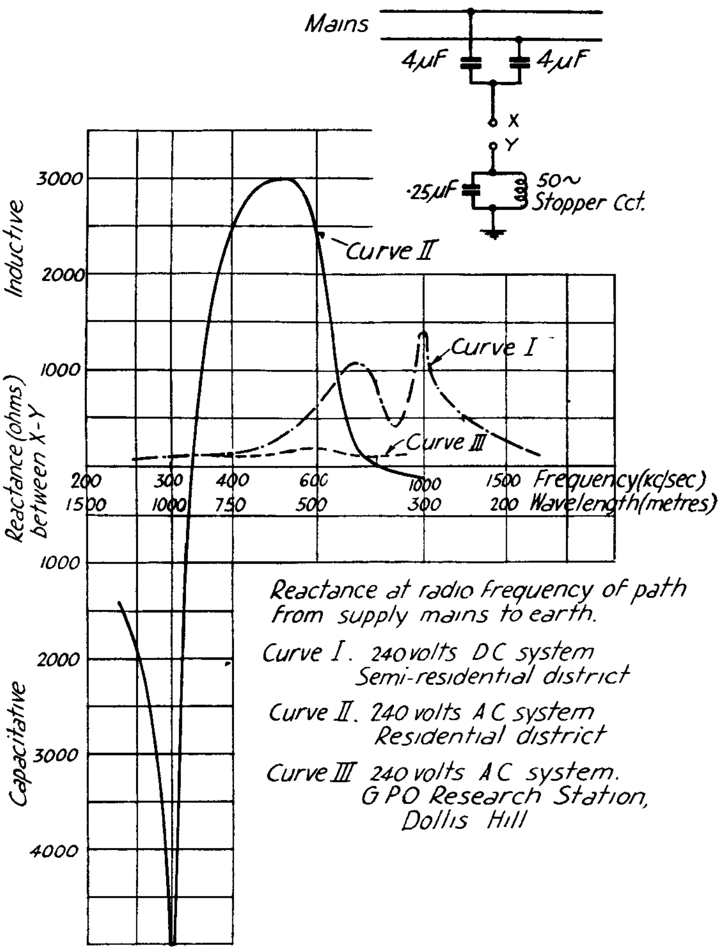


FIG. 1.

plant of high capacity to earth would have a marked effect on the mains impedance within a considerable radius.

There is no doubt that an appreciation of this subject of mains impedance will enable further progress on the suppression of H.F. interference to be made. Its consideration in the case of the overhead feeders of a tramway system when in normal operation, may reveal unsuspected peculiarities in their behaviour at broadcast frequencies, and may lead to the evolution of other methods by which tramway interference can be treated.

*Low Frequency Interference.*

Interference, propagated in the form of low frequency currents is a further cause of complaint. This type of interference affects only those types of receiver which derive their power from electric mains. Disturbances of this nature arise mainly in the case of D.C. mains and is brought about by various types of plant, which set up audio frequency ripples on the mains fed by or feeding into such plant. These ripples are not radiated from the house wiring to any extent, but in many cases pass through the power supply unit of the radio receiver and cause a steady hum in the loud-speaker. Increased smoothing in the power unit provides a cure and is often applicable in cases where the adoption of remedial measures at the source of the interference is impracticable.

*Low Frequency Harmonic Content of A.C. Mains.*

In the case of A.C. mains, a very large number of upper harmonics of the fundamental frequency of quite considerable magnitude may be present. Recent analysis of a nominal 416 volt, 50 cycle, 3-phase system showed the presence of practically every harmonic up to the 60th, at which point the observations were suspended, although there is no doubt that the harmonic content spread much above this range. The even harmonics were in general much smaller than the odd, a notable exception being the 2nd which had the greatest amplitude of all. The magnitude of the harmonics was continually changing by as much as 100%. Table No. 1 below gives approximate average values of the amplitude of every harmonic of 0.2 per cent and over.

TABLE NO. 1.

Showing harmonic content of A.C. Supply.

| Harmonic No. ... | 2 | 3 | 5 | 7 | 31 | 47 | 49 |
|---|---|---|---|---|---|---|---|
| Magnitude % ... | 0.8 | 0.7 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 |

As will be seen later from the consideration of smoothing in mains-operated sets it is improbable that the harmonics of A.C. mains would seriously interfere with broadcast reception.

*Ripple on D.C. Supply.*

The permissible mains ripple on mains-operated sets is governed by the amount of hum which can be tolerated in the loud-speaker and this will vary for different classes of loud-speaker, types of broadcast matter and operating conditions relative to level of reproduction.

The ratio of output ripple to input in a commercial receiver is very nearly constant up to quite considerable values of input ripple, and in its elimination, the best results are obtained by smoothing the filament and anode supplies to the same extent, no advantage resulting from the superior smoothing of the anode circuit which is usual in most commercial sets.

From a very comprehensive series of tests on a 200 volt D.C. supply, some useful data as to permissible ripple has been obtained. Detailed results are given in Table No. 2, from which it will be seen that the maximum allowable ripple, even under the most stringent condition, (that the hum in the loud-speaker should be unobjectionable during silent periods) is considerable, provided that adequate smoothing is used.

At the same time the Table shows that the allowable ripple is considerably reduced if inadequate or incorrectly designed smoothing circuits are used.

## Table No. 2.

Maximum allowable ripple in a 200 volt D.C. supply at various frequencies, under various broadcast conditions and with various amounts of smoothing.

| Broadcast Conditions. | Maximum allowable ripple in volts. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Normal Smoothing of a good commercial receiver. | | | Approximately one half normal smoothing. | | | No Smoothing. | | |
| | Frequency of ripple in supply. | | | Frequency of ripple in supply. | | | Frequency of ripple in supply. | | |
| | 50 | 300 | 600 | 50 | 300 | 600 | 50 | 300 | 600 |
| Silent Periods ... | 96 | 62 | 150 | 93 | 30 | 75 | 4.8 | 0.4 | — |
| Normal Speech ... | 96 | 138 | >150 | 93 | 67 | 138 | 4.8 | 0.9 | — |
| Soft passages in music adjusted to normal output for a small room | 107 | >150 | >150 | 103 | 136 | >150 | 5.3 | 1.9 | — |
| Loud passages ... | 128 | >150 | >150 | 124 | >150 | >150 | 6 4 | 5 4 | — |

## METHODS ADOPTED IN TRACING SOURCES OF INTERFERENCE.

A portable radio receiver is generally used for the purpose of tracing the source of the interference. A scrutiny of the questionnaire form relating to the complaint will sometimes reveal that by logging the times of commencement and cessation of the interference, the complainant has evidence as to its source and in such a case only confirmation is necessary. When no such information is available, the first step is to ascertain the means whereby the interference is propagated, *i.e.*, whether by direct radiation or *via* the electric supply to the building. This is accomplished by breaking the main switch of the electric supply to the building and noting the effect on the interference as received on portable receivers of the battery type. If there is no reduction in the volume of the interference then it is reasonable to suppose that it is due to direct radiation and the directional properties of the portable receiver can be used in tracing the source. Cases of direct radiation are, however, comparatively few, and the breaking of the main switch will often result in a considerable reduction in the interference. The portable receiver is again used to trace the source of the trouble; if the run of the street mains is followed, it will be found that the interference increases in volume as the source is approached. At the point of maximum volume, enquiries in the immediate neighbourhood should reveal what plant is responsible for the trouble. The character of the interference, as heard on a radio receiver, will also sometimes enable the search for the source to be narrowed down considerably.

The results of these investigations will indicate the type of interfering plant and enable an idea to be formed of the necessary apparatus required to effect a cure. The experimental fitting of such apparatus is then proceeded with in order to demonstrate the effect on reception.

## TYPES OF INTERFERING PLANT, AND PREVENTIVE DEVICES.

The principal types of interference which have been investigated at present are those occasioned by the operation of—

(*a*) Motors and Generators of both D.C. and A.C. types.

(*b*) Battery charging rectifiers.
(*c*) H.F. Medical apparatus.
(*d*) Flashing signs, Electric ovens and heating pads.
(*e*) Neon signs.
(*f*) Lifts.
(*g*) Tramways.
(*h*) Trolley Buses (trackless electric cars).
(*i*) Mercury Arcs.

*Electric Motors and Generators.*

Owing to the very general use of electric motors, interference due to such plant is probably the most important when viewed from the aspect of the number of cases in which it arises, although the area over which the interference from a machine is apparent may not be so great as that due to other types of plant.

The interference from electric motors appears to be wholly high frequency in character and is frequently very severe. The area over which interference is experienced is of course variable, depending on such considerations as the intensity of the interference at the machine terminals and the electrical characteristics of the mains, *i.e.*, their high frequency impedance to earth.

Experience shows that motor interference rarely extends to a greater distance than 200 yards and usually becomes inaudible at 50 yards.

The problem involved in effecting a cure is to form a low impedance path for the high frequency currents to flow to earth. This is accomplished by connecting from each main to earth a condenser of large capacity, usually 2 microfarads. It is sometimes found necessary to insert a choke in each main for the purpose of increasing the impedance of the mains, thereby rendering the condensers more effective in shunting the H.F. currents to earth. Fig. 2 shows the

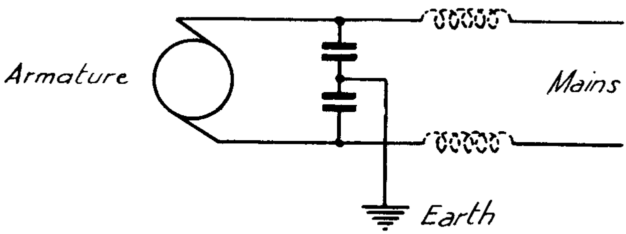


FIG. 2.

arrangement in a schematic form. The above remarks apply equally to motors of D.C. and A.C. types. The ordinary form of induction motor has been found to give little trouble, and in some cases is definitely free from objection. This type of motor will, however, be more fully considered in relation to its use for electric lifts.

Electrical generators produce both high and low frequency interference. In the case of small generators the interference is as severe and arises from the same cause as in electric motors. An exactly similar cure is effective. Experience to date of large generators indicates that as a rule they do not cause severe high frequency interference. The usual location of generating stations at some distance from residential districts is perhaps a reason why few complaints have been received; at the same time it is to be observed that investigations at a modern power station indicated that very little H.F. currents are generated.

As regards the low frequency ripple from large generators, complaints of interference from this cause are occasionally received. So far as the commutation in such machines is a cause, the sudden change of current in the short circuited element gives rise to the generation of E.M.F's in all armature coils due to the transformer action between them and the short circuited turn at the frequency of the commutator bars.

This phenomenon is seen very clearly in the oscillographic record of the E.M.F. in a single turn of a 2-pole D.C. machine reproduced in Fig. 3.*

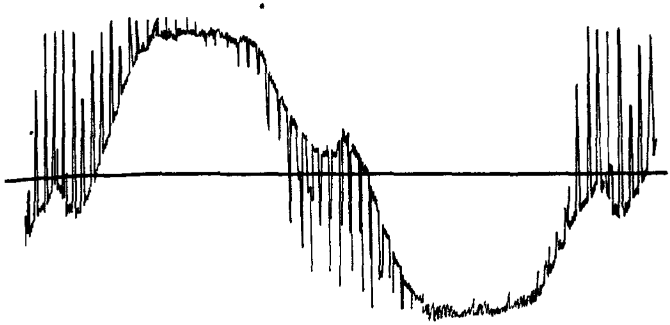

FIG. 3.

* Reproduced from "The Diagnosing of Troubles in Electrical Machines," by Professor Miles Walker.

Superimposed upon the general waveform of the E.M.F. are severe oscillations, the amplitude of which reaches the maximum value of the E.M.F. due to the main field when the coil is being short circuited. Such oscillations produce the low frequency ripples frequently observed in the supplies from such machines. For a machine with 120 commutator segments and a speed of 300 r.p.m. the ripple frequency would be 600 cycles/sec.

The well known phenomenon of tooth ripple is not considered in this paper, but it is known to be at times a source of low frequency interference.

Cases of low frequency ripple are very difficult and expensive to cure at the source. A solution is to be found by adequate smoothing in the supply circuits of the receivers fed from mains connected to such a source. Modern machines are designed with a view to the limitation of such ripple and in the future such trouble as has been experienced should tend to decrease.

It has already been stated that H.F. interference from a motor can be experienced in the absence of sparking at the brushes and this appears to be borne out by the following considerations:—

During the period when a winding element is being short circuited by a brush, the current in that element has to die away to zero and then increase in the reverse direction to its full value.

A reproduction of actual oscillographic records of commutation is shown in Fig. 4.* Sparking at the brushes is caused by the sudden changes of current either at the beginning or end of the short circuit as indicated by curves A, B and C, Fig. 4. Curve D represents good commutation. Providing there is an absence of rapid changes in current at the ends of the commutation period, sparking would not be apparent as for example if the current followed some such curve as the hypothetical one X*ab*Y. Here, however, there appears a very sudden change of current *a* to *b* which would give rise to H.F. currents in the armature coils which in turn would set up changes of potential in the winding with respect to earth. Such a curve is probably exaggerated, but in many cases the current during commutation may approach such

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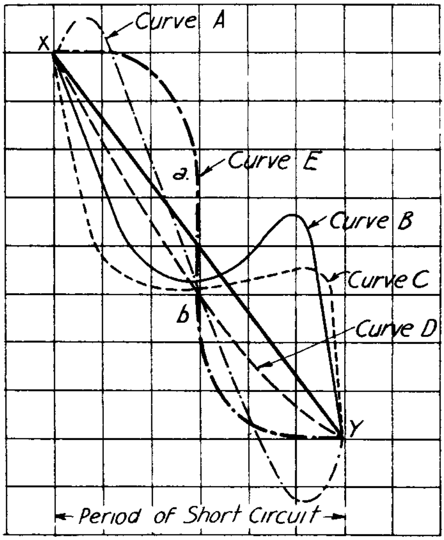
* Reproduced from "Dynamo Electric Machinery," by Silvanus Thompson.

conditions and thereby lead to the phenomenon of interference without sparking.




Curve A - Light Load
" B - Under Commutation
" C - Under Commutation at end of period - Medium Load
" D - Good Commutation approaching the ideal represented by the straight line X-Y
" E - Hypothetical Curve.

FIG. 4.

*Battery Charging Rectifiers.*

Rectifiers of the rotary commutator type, used for charging wireless and car batteries, frequently give rise to very severe interference over distances up to about 200 yards. The commutator arrangement is shown on diagram Fig. 5. The interference in these cases is caused mainly by direct radiation from the plant (including the batteries under charge). The H.F. currents transmitted along the mains are of comparatively small importance, but it is necessary to provide also against this component of the disturbance. It is a very difficult matter to cure the directly radiated interference, chiefly on account of the fact that the batteries on charge are

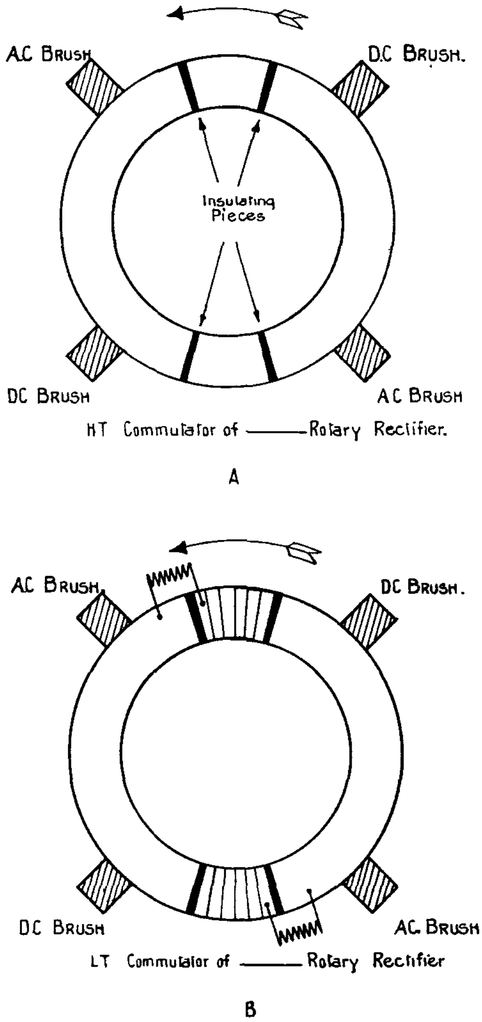



FIG. 5.

part of the radiating system, and their capacity to earth is very high. Nevertheless, following experimental work carried out on a well-known make of full wave rotary rectifier, a remedy has been found which has proved very successful except in the case of the heavy duty type. Fig. 6 shows the remedial apparatus fitted and it will be seen that condensers

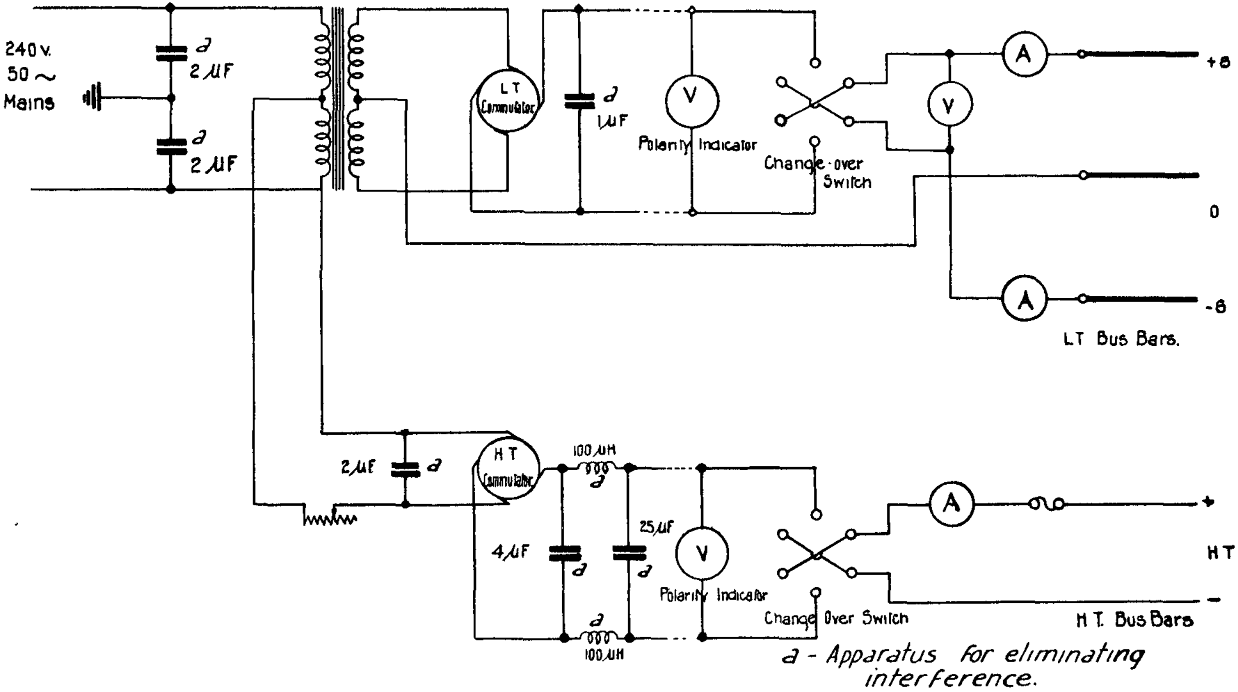

240 v.
50 ~
Mains
a
2 μF
a
2 μF
LT Commutator
a
1 μF
Polarity Indicator
Change-over Switch
V
A
V
A
+6
0
-6
LT Bus Bars.
HT Commutator
2 μF
a
100 μH
a
4 μF
a
25 μF
a
V
Polarity Indicator
Change Over Switch
A
+
HT
–
H.T. Bus Bars
a
100 μH
a - Apparatus for eliminating interference.

FIG. 6.

are necessary across both the L.T. and H.T. output and also across the input to the transformer, the latter dealing with the mains propagated disturbing currents. In addition H.F. chokes have to be inserted in the H.T. output leads. Further investigation of machines of the very heavy duty type, such as are installed in cinemas for supplying direct current to the arcs and to the batteries working talkie apparatus, will be undertaken as opportunity offers. As the use of these machines in cinemas is becoming more common, the problem is one of some importance.

There are several other types of battery charging rectifier in use. Valve rectifiers in general cause no trouble, but in a few cases, where complaints have arisen, the interference has been traced to a faulty or unsuitable type of valve. Vibrating reed rectifiers often cause considerable interference, but a remedy is generally possible by the addition of high frequency chokes in the mains and condensers across the mains and vibrating contacts.

*High Frequency Medical Apparatus.*

A special investigation has been carried out by the Post Office into this type of interference. A high frequency medical set, or " ultra-violet ray " apparatus, as it is sometimes called, operates in somewhat the same way as a spark wireless transmitter. Damped waves are generated by shock excitation of an oscillatory circuit, and the voltage is stepped up to a very high value by a high frequency transformer. The wave-length of these sets is usually between 2000 and 5000 metres, *i.e.*, a frequency of 150 to 60 Kc. One end of the secondary is joined to an electrode which is applied to the patient, and the other end is connected, either conductively or capacitatively to the supply mains, whereby the high frequency currents flow into the patient, through his capacity to earth, and return *via* the supply mains, see Fig. 7. An arrangement worse than this from the point of view of interference with wireless receivers is difficult to imagine, including as it does a transmission which necessarily spreads over a wide band of frequencies. Even the most selective receiving set is unable to cut out this interference, which often extends its influence over a range of as much as 300 yards.

The method of cure advocated as a result of the experimental work referred to, is to re-design the apparatus in such a way that a closed secondary circuit is provided, earth currents thereby being reduced to a minimum.

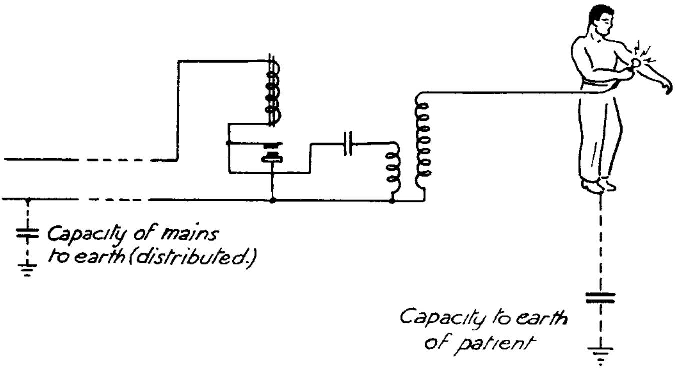



FIG. 7.

Various reasons have been advanced by the manufacturers and vendors of such apparatus against such a change in design, which do not however seem to be insuperable, and the desirability of such a re-design from the technical point of view cannot be too strongly urged. There is another method of rendering such apparatus innocuous which involves the construction of a complete metallic screen, large enough to enclose both the apparatus and the patient. The four walls, the floor, and the ceiling of the room in which the apparatus is used are covered with wire mesh and two large condensers (say 2 $\mu F$) connected in series across all electrical circuits entering the room, the middle point of such condensers being joined to the screen. A complete cure results.

A full description of the construction of such a screened room is given in a paper read before the C.C.I.R., by Professor Absalom Larsen, at Copenhagen in June, 1931.

It is thought that few owners of high frequency sets would be willing to go to the expense of fitting out a room with wire mesh, but in the case of hospitals where X-ray and diathermy work is carried on, the method should be of value.

This method has been adopted in America and elsewhere and is an appropriate solution where such apparatus is in constant use on a large scale as well as in hospitals and institutions where X-ray and diathermy work is carried out.

It is hardly appropriate perhaps to the case of the general medical practitioner or in those instances where only occasional use is made of such apparatus.

In such cases the use of a small completely screened cage, with suitable door for ingress, installed in a practitioner's consulting room may be a more economically practicable solution. Failing the use of such methods as have been described, the restriction of the use of such apparatus to periods outside the usual broadcasting hours is the only alternative and is the one which commends itself to the case of the private use of H.F. medical apparatus. It is understood that such restriction is enforced by local regulations in some countries.

*Flashing Signs, Electric Ovens, and Heating Pads.*

The simplest possible type of flashing sign consists of an electric lamp switched on and off at regular intervals by a thermostat or other device.

Interference from this class of apparatus takes the form of a " plop " or " bang " in the loud-speaker every time the thermostat operates. The cause of this interference has been clearly established.

Referring to Fig. 8, consider the lead AB which connects the thermostat to the lamp. When the contacts are closed,

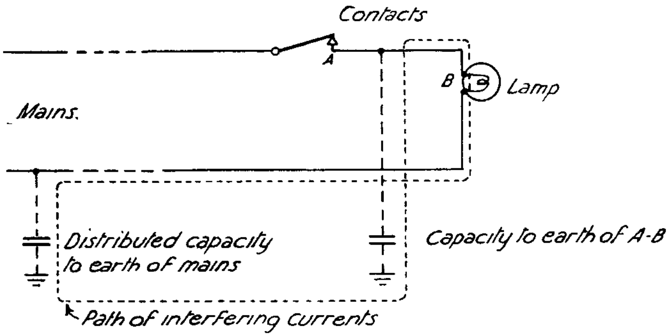



FIG. 8.

the potential of this wire with respect to earth is 240 volts positive, *i.e.*, the potential of the upper main on the diagram. When the contacts are open, however; the potential of this wire immediately falls to zero, or to the potential of the other main. Hence every time the thermostat operates, the length of wire AB changes its potential by 240 volts. This wire has a definite capacity to earth, of the order of 10 to 20 micro-

microfarads. The sudden change of potential of AB causes an instantaneous current to flow through this capacity to earth, whence the circuit is completed *via* the supply mains, as shown on Fig. 8. It will be seen that, as in the case of high frequency medical apparatus, it is the provision of an earth path for the H.F. currents which leads to the interference. The disturbance thus superimposed on the supply mains can cause interference up to about 100 yards. A similar explanation holds good in the case of A.C. mains. To cure this interference one or both of the following remedies may be adopted: Firstly, a constant potential screen may be interposed between the apparatus and earth, in order to confine the currents in the wire AB to itself and the screen. This can be achieved by surrounding the apparatus with a complete metallic screen, and connecting the screen to the mains *via* 2 $\mu$F condensers. The path of the intercepted currents is then as in Fig. 9, from which it will be seen that flow along that section of the mains external to the screen is prevented.

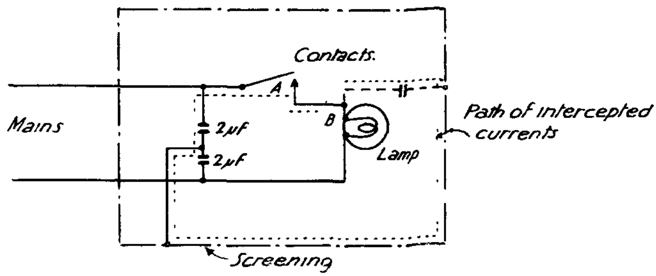



FIG. 9.

An alternative method is shown in Fig 10, in which a high frequency choke in the mains in series with the flasher, and a condenser and resistance " quench circuit " across the contacts is used.

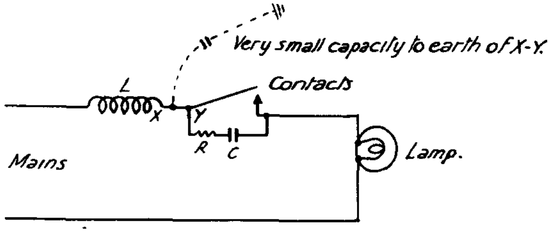



FIG. 10.

When the values of L, C and R are correctly chosen, this arrangement prevents the current in the main circuit from increasing or decreasing rapidly when the contacts are operated. It should, however, be noted that the length of wire XY joining the choke to the contacts still suffers a sudden change of potential equal to the mains voltage, when the contacts close. Hence it is essential to minimise the capacity to earth of XY by mounting the choke very close to the thermostat and to join the two together by a very short lead. It is also advantageous to screen the choke coil, since the turns nearer the thermostat suffer potential changes in the same manner as does the wire XY.

A sufficient degree of screening can be attained by connecting the inner end of the winding to the thermostat. It can be stated that the first method is the better when the whole of the apparatus is enclosed or can easily be enclosed in a metal case, and that the second method should be employed when the flasher mechanism is some distance from the lamp or heater element.

Multiple contact signs are becoming very popular for advertising purposes, and a number of complaints of interference from them have been dealt with. Interference is caused in exactly the same way as by a single contact sign, and the method of cure is by the first method given for that type of apparatus.

The flashing mechanism usually consists of a rotating drum arrangement driven by a small electric motor, which makes and breaks a large number of circuits. It is generally a simple matter to enclose the whole of the flasher mechanism in a metal box, and to run the leads from the flasher to the lamps in lead-covered cables. The lead sheaths must be carefully bonded to the metal box, and the whole screening system connected to the mains *via* 2 $\mu$F condensers.

In order to provide for the earthing of the screens it has at times been found desirable to make the earth connection *via* a H.F. choke of negligible D.C. (or L.F. A.C.) resistance. Direct earthing in such cases will sometimes reduce the effectiveness of the cure by reason of the impedance to earth of the mains furnishing a parallel path for the H.F. currents.

*Neon Signs.*

There are two types of neon sings, the high frequency type and the low frequency type; for the former, frequencies of about 60 to 150 kilocycles are used.

High frequency neon signs are used inside shop windows, and in similar positions where it would be dangerous to use the low frequency type on account of the risk of shock. These signs are similar in principle to high frequency medical appliances, and the secondary of the high frequency transformer is connected across a neon tube. The secondary circuit is closed through the tube and therefore such signs ought to cause no interference to wireless reception.

It has been found, however, that the insulation of one end of the secondary winding from the primary turns of the H.F. transformers incorporated in these signs, often provides an alternative path for H.F. currents *via* earth and the supply mains. The currents flowing from secondary to primary are both capacitative and true conduction currents and flow *via* the inadequate insulation. It should be mentioned that the quality and amount of insulation usually provided is quite adequate for the normal working of these signs.

Interference due to this cause is very serious, and can be heard, at a distance of 200 yards. In such cases the remedy is to decrease the flow of current between the Secondary and Primary windings of the transformer. This can be achieved by improved methods of insulation. The use of a metallic screen between the windings has recently been considered for this purpose and arrangements for an experimental trial are in hand.

In the case of one make of sign there are two step-up transformers, with their primaries in parallel and their secondaries in series. It was possible to provide a remedy here by connecting together the outer ends of the secondaries, *i.e.*, those ends of the secondary winding nearer the primary. This is shown in Fig. 11.

A slight out-of-balance in the capacity to earth of the two sides of the system could be eliminated by placing a very small capacity to earth at a suitable point along the neon tube.

Although several complaints have been received of interference from low frequency neon signs, these signs do not as a rule give trouble. One firm specialising in the manufacture of these signs, adopts a capacity balance method similar to that described above for high frequency signs.

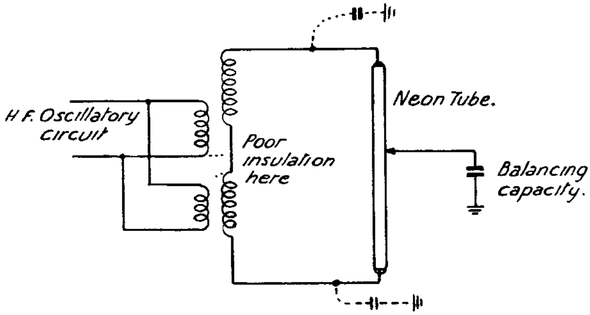



FIG. 11.

In a few cases a low frequency ripple has been set up on the mains by these signs. As mentioned in an earlier section of this paper, such interference only affects mains-operated sets, and the cure is to increase the smoothing in the complainant's mains supply units.

*Lifts.*

Interference due to lifts emanates from the operating motors and the controller. The noise due to the motors is continuous during the operation of the lift whilst the controller noises consist of loud " plops " in the receiver at each make and break of the various contacts in the controller. Of the five different types of induction motors that have been concerned in lift interference only two have been found to give trouble. The single phase repulsion induction motor and the " Bandy " motor which is a special type of the single phase repulsion induction motor, are interfering types and since the armatures are normally short circuited, the fitting of the usual condensers across the brushes cannot effect a cure. In this case it is necessary to insert H.F. Chokes of approximately 180 $\mu$H in the mains and to bridge the mains on the controller side of the chokes with two 4 $\mu$F condensers in series, the common point of the condensers being well earthed. As distinct from the ordinary " motor cure " it has been found that 4 $\mu$F condensers are generally necessary. This is probably due to the fact that lifts are usually in very close proximity to the affected receiver and a lower impedance path must be provided to confine a greater proportion of the H.F. currents to the immediate neighbourhood of the lift.

The same cure is also applicable to lift motors of the D.C. type which usually give rise to more severe interference than the A.C. machine.

The noises due to the controllers although greatly reduced are not eliminated by the above arrangement and it is necessary to fit one 2 $\mu$F condenser across each contactor. The addition of such condensers results in reasonable reception conditions being attained, but to obtain complete elimination necessitates the use of a " spark quench " circuit consisting of a condenser and resistance in series across the contacts. A very definite value of resistance is required before a cure is complete and a " spark quench " circuit is therefore limited in its effectiveness to the cases of D.C. lifts where the magnitude of the current broken is constant.

*Tramways and Trolley Bus Systems.*

Although less than 10% of the total number of electrical interference complaints received by the Post Office are due to tramways or trolley bus systems, this type of interference has attracted a great deal of attention from the public, and has therefore assumed considerable importance due no doubt to the widespread effects produced; one source of interference will probably affect hundreds of listeners. In both systems of transport the interference is picked up as radiation from the overhead feeders acting as aerials. The H.F. currents are generated in the wiring and electrical equipment of the vehicle and conveyed by the feeders over the whole network.

The problem has so far been treated on the basis of applying a remedy for the existing state of affairs with the minimum of expense and avoidance of alteration to the equipment. In the case of ordinary tramcars, where such expedients as transposition of the field coils of the driving motors, from the earth side of the armature to the trolley arm side have been tried, a reduction of the interference has resulted. By transposing the field coils in this manner their high impedance to H.F. currents serves to limit the passage of such currents to the overhead feeder.

As will be seen later by consideration of the trolley bus case, the normal location of these coils at some distance from the feeder seriously reduces their effect as stopper coils. It has been found that the collector noises cause only a very small proportion of the interference.

The electrical arrangements of trolley buses differ from those of trams in respect of the double feeder connection to the mains and the absence of any earth connection. Interference is generally much more acute in the case of trolley buses and the investigation of a cure followed somewhat different lines from that pursued in the case of trams. The splitting of the field coils into two portions and their connection into each trolley arm circuit was found to be inadequate owing to their location at some distance from the feeders and also on account of the fact that the half coils exercised a much smaller choking effect than the complete coil. As offering the most practicable immediate solution therefore, attention was directed to the fitting of special choke coils constructed

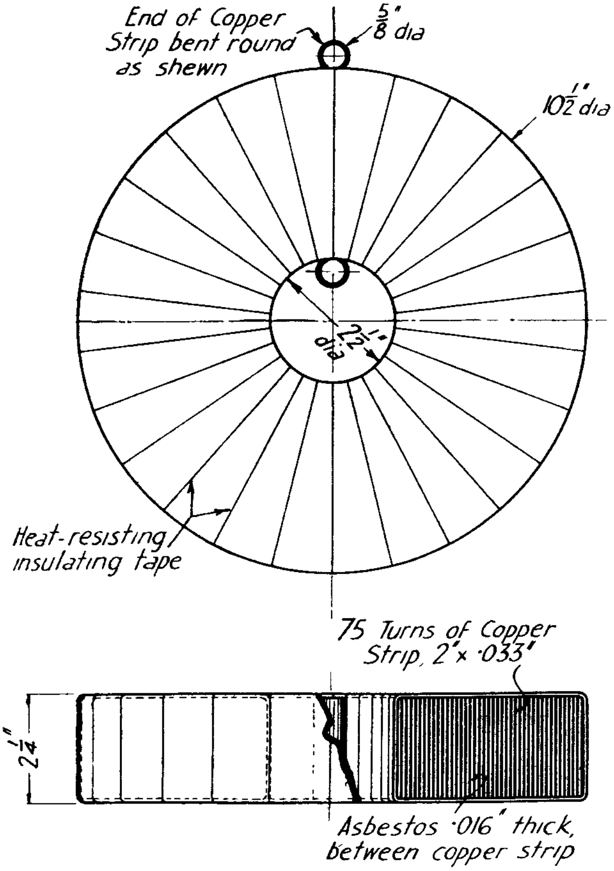



FIG. 12.

to offer a high impedance at the frequencies of the broadcasting transmitters servicing the affected area. These coils are inserted one in each feeder and are mounted on the roof of the bus in order that they may be connected as near to the feeders as possible. Actual trial showed that the position of the coils in relation to the feeder was of considerable importance, their effectiveness being greatly reduced by mounting them in the drivers' cabin.

The experimental coils were not suitable for direct fitting in a position exposed to the weather and the provision of a

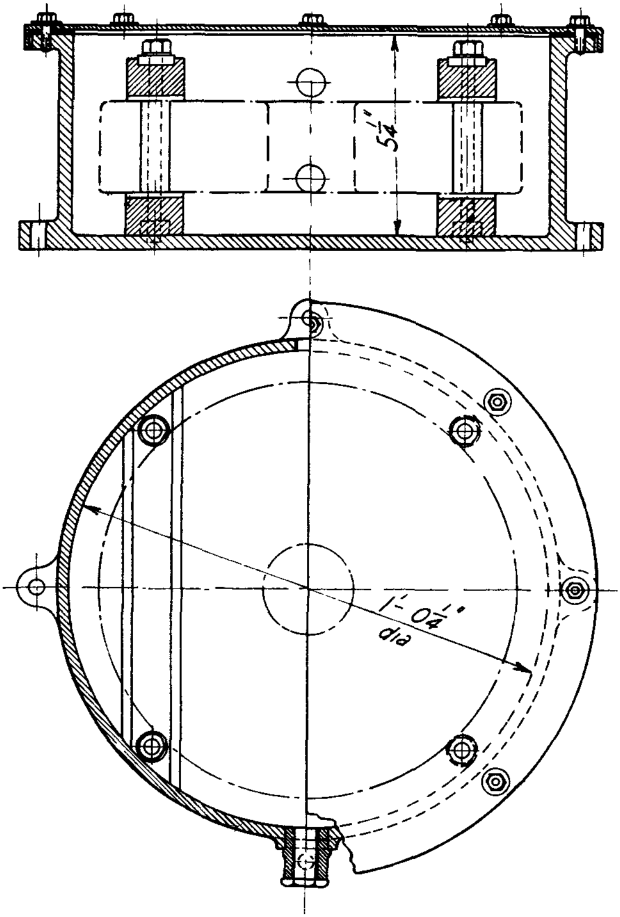



FIG. 13.

suitable metallic case was undertaken as a result of experiments on the effects of such a case on the resonant frequency of the coils.

Choke coils, constructed as shown in Fig. 12 and mounted in cases shown in Fig. 13 were successfully fitted to the London United Tramways trolley buses at Teddington. They offer a very high impedance to frequencies covering the band of the two London transmitting stations. Impedance-frequency curves for one of these coils is shown in Fig. 14.

When the whole of the fleet of 60 buses had been equipped with coils, elimination of disturbances on the

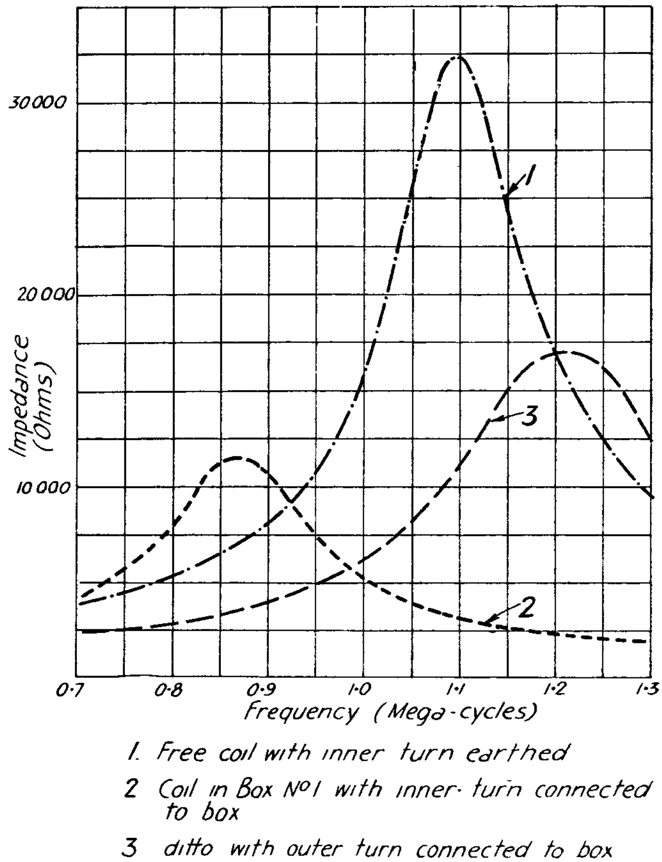



FIG. 14.

London Regional (356 metres) programme resulted. In addition, only occasional faint clicks and noises were noticed when critical observations on the London National (261 metres), and Midland Regional (399 metres) programmes were made. Although the coils were not designed to deal with long wave transmissions, observations on Daventry (1554 metres) programme showed a fair improvement.

*Mercury Arc Rectifiers.*

A large number of complaints have been received from towns where mercury arc rectifier substations have been installed as part of the D.C. electricity supply system. The interference takes the form of a powerful low frequency ripple set up on the mains, which affects mains-operated receiving sets over the whole area served by the substation.

So far as can be ascertained, mercury arc rectifier substations are equipped principally with the 3-phase or 6-phase types. With 50 cycle input these give rise to ripples of 150 cycles and 300 cycles fundamental frequencies respectively. The suppression of these by means of power chokes located at the substation is usually inordinately expensive. With a view to obtaining an alternative remedy at the source, 12-phase rectification has been tried experimentally with success. The resulting 600 cycle ripple being of small amplitude causes very little interference.

It is of interest to note that an arrangement much favoured by manufacturers of mercury vapour rectifiers is the use of 6-phase rectifiers on each side of the neutral main with the two systems 30 degrees out of phase. Tests have shown that this is not the equivalent of a 12-phase system and does not reduce interference.

At present small glass rectifiers cannot be made with the necessary number of electrodes to permit of 12-phase working, and it is not economical in the case of stations of small power to increase the number of such rectifiers to permit of 12-phase working. Similarly for very large powers it is too expensive to convert from 3 or 6-phase working to 12-phase.

From the foregoing it will be seen that financial considerations may preclude the treatment at the source of interference from mercury arc rectifiers. In these circumstances adequate smoothing of the mains units of radio receivers furnishes a solution of the difficulty, and this is the remedy which has been adopted in the past in those towns where complaints have arisen.

Mercury arc rectifiers are also used on consumers' premises for operating D.C. plant off A.C. mains; lifts, electro-plating apparatus and cinema arcs are examples of such plant. Rectifiers used in this way sometimes give interference over a small area and local cure at the radio receiver is the solution.

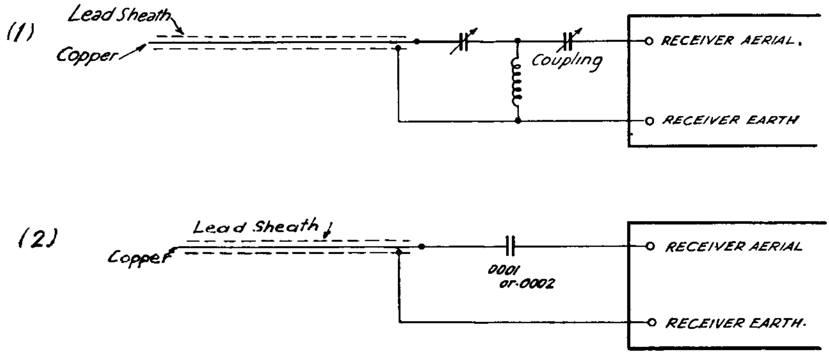
## METHODS OF CURING INTERFERENCE AT LISTENERS' PREMISES.

Although efforts are always made to locate and treat the actual sources of electrical interference, it sometimes happens that this procedure is impracticable. In industrial districts, there is often considerable electrical plant in the vicinity of the complainant's premises and it is then difficult to attribute the interference to any one item. Investigation is very complicated and expensive, and, in such cases, an endeavour is made to cure the trouble at listeners' premises.

As already observed, high frequency interference is nearly always propagated over the electricity supply mains. It enters listeners' premises *via* the mains and is radiated from his house wiring. After a preliminary test has shown that the interference is entering the house in this way a cure can be applied by inserting a high frequency filter in the mains where they enter the house. The general form of such a filter is identical with that normally fitted to electric motors, and consists of two 2 $\mu$F condensers across the mains with centre point earthed. H.F. chokes of approximately 600 $\mu$H inductance can also be inserted if the condensers alone do not effect a cure.

It is sometimes possible to reduce H.F. interference from nearby sources by an alteration in the direction of the receiving aerial or by the use of a counterpoise earth. Good results have occasionally been obtained by these means. Recent investigation has shown that the use of a screened aerial lead-in to the receiver may be very effective. In cases where there is sufficient space for a listener to erect an outdoor aerial well away from his house, a screened lead-in will prevent any radiation by the house lighting system from affecting the receiver. For perfect results the tuning coils in the receiver must also be screened, but this is normal practice in modern sets.

Ordinary lead-covered electric lighting cable is used for the lead-in. The aerial is connected to the core, and earth is connected to the lead sheath. It is then possible to use a buried earth in the ideal position, immediately beneath the aerial. No earth connection is employed for the receiving set other than that furnished by the lead sheath of the lead-in. Fig. 15 illustrates the method of connecting up at the receiver end.




*Screened Aerial Lead-in for Wireless Reception.*

*(Arrangement (1) gives the better result)*

FIG. 15.

It has been found that a very long screened lead-in may cause some slight loss of signal strength, but this disadvantage is outweighed by the resulting freedom from interference.

## GENERAL DISCUSSION OF ALTERNATIVE REMEDIES.

The question of the most suitable method of dealing with interference from industrial machinery must be determined not only from the economic standpoint, but from considerations of convenience and expediency and degree of completeness of the cure adopted. Treatment at the source as against treatment of the radio receiver and aerial system or of house wiring presents perhaps the most important aspect of this question.

From its widespread influence, tram and trolley bus interference exemplifies the desirability of designing electrical plant which shall be, as far as possible, innately free from interference. The alternative of the subsequent adoption of preventative measures in the form of additions to the equipment is both inconvenient and costly. The tram and trolley bus case is receiving very close attention, the interests concerned with the provision of new plant co-operating with the Post Office and the B.B.C. in an endeavour to arrive at the best solution. It is hoped that, ultimately, it will be possible to instal tramways and trolley bus equipment which is essentially free from interference. As will have been gathered in other sections of this paper it is highly desirable that the same principle should be observed in the production of other types of equipment, such as, for example, motors and H.F. medical apparatus. In the case of mercury arc rectifiers, developments in the manufacturing processes relating to such plant, whereby the 12-phase method of working may be rendered an economical proposition, will furnish a simple solution.

## OTHER SOURCES OF INTERFERENCE.

### *High Tension Transmission Lines.*

Only a few cases of interference from high tension transmission lines have occurred to date. Experience in other countries indicates, however, that such systems are potential sources of radio interference and the development of the grid system of power distribution in this country is being watched from this point of view.

An important cause of radio interference is the corona discharge from high voltage lines. The presence of faults also on such lines gives rise to surges which result in interference over considerable areas especially in those instances where secondary circuits, within the influence of the high tension line, are available as carriers. In the case of lines which are in a reasonably good condition from the operating point of view interference may be experienced through line discharges and plant surges. It would seem that a much higher maintenance standard is required to meet radio conditions than is necessary for normal operation, particularly in regard to cleanliness of, as well as closeness of contact of, the lines and tie wires to the insulators.

### *Interference with Short Waves.*

So far the problem has been concerned mainly with the alleviation of the interference as it affects the reception of medium and long wave broadcast stations, *i.e.*, around 300 and 1500 metres respectively.

Recent developments in radio technique are making possible the utilisation of short waves and ultra short waves for Broadcasting and Television. Whilst this increased use of the higher frequencies is very desirable to relieve the congestion of the ether, further types of plant become involved in the interference problem. The chief among these is the ignition system of internal combustion engines. Interference from such systems is by direct radiation, the intensity of such interference being greater on short wave-length signals than on long. In connection with aeroplanes equipped with wireless the question is already of paramount importance and nothing short of complete metallic screening of the whole ignition system appears to be sufficient to produce conditions for satisfactory reception. A large number of aeroplanes are fitted for wireless reception and, of necessity, the cure will have been applied. It is accordingly unlikely that such machines will give very much trouble to listeners when in the future the use of short waves is more generally extended to Broadcasting.

A paper has been published describing the work on ignition systems carried out by the Bureau of Standards. This paper deals at considerable length with the constructional and maintenance difficulties arising from the complete electrical screening of the ignition systems of aeroplane engines.

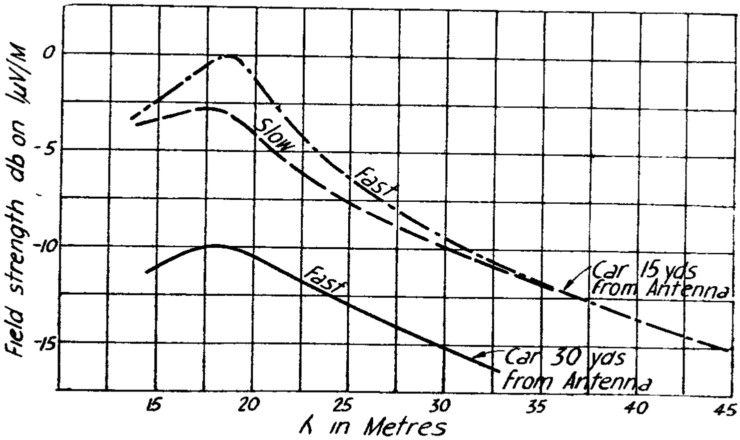
This matter is being closely followed by manufacturers in this country, where a suitably designed ignition system is marketed.

Another potential source of trouble lies in the ignition systems of motor cars and may furnish grounds for a large proportion of the complaints in the future.

In America the practice of installing radio receivers in motor cars is fairly general and the interference to such receivers has received much attention in that country.

Field-strength measurements indicate that in general the interference to reception of signals transmitted on the short wave band, shows a well-defined maximum for some value of the wave-length in the band, with a steady decrease in intensity for wave-lengths above and below this value.

Fig. 16 gives the actual field strengths of the short waves, comprised in the 14 to 50 metre band, radiated from the magneto of an ordinary commercial car. The maximum intensity at about 18 metres on this particular car is clearly




*Field Strength of Ignition Noise from a 20 H P, 4 Cylinder, Magneto ignition, Motor Car measured on 8 metre Vertical Antenna*

FIG. 16.

illustrated. The diagram also shows the increased interference at higher engine speeds and for decreased distance between the car and the receiving aerial. Other makes of car with their particular ignition systems, although showing similar characteristics, will doubtless differ in respect of actual intensity and wave-length of the maximum interference. Experience at the Baldock receiving station, which is located at some distance from public roads, indicates that some types of commercial vehicle are capable of producing very serious interference to the short-wave telephone services operated there.

Complete screening as for aeroplane engines, whilst definitely effective, is a very expensive and inconvenient method of dealing with interference from motor vehicles.

Damping resistances in the leads to the sparking plugs, mounted as close as possible to them, combined with the use of condensers has been recommended as a suitable solution to the problem.

Actual trials with " suppressor " coils, mounted close to the plugs and with screened leads between the plugs and the distributor, have given satisfactory results on medium wave band transmissions.

By essentially confining the oscillatory circuit to the neighbourhood of the plug, the frequency of the oscillations set up may be increased to a value well outside the broadcast band.

In presenting this resumé of the present position in this country of the methods of investigation and treatment of cases of interference with broadcast reception it is desired to emphasize the desirability of close co-operation between the interests concerned.

Where such co-operation exists the difficulties are being met with satisfaction to the listeners and with the minimum of trouble and difficulty to the users of the electrical plant concerned.

Failing this co-operation the design of suitable remedial measures is a matter of great difficulty.

An important factor which should not be overlooked is the more critical attitude adopted by the public to the reception of broadcast programmes and for this reason alone, the pressure for the avoidance of all types of electrically interfering plant is likely to be made prominent.

My acknowledgments for much useful information are due to the British Broadcasting Corporation and particularly to the Radio Staff in the Engineer-in-Chief's Office dealing with this problem.

BIRCH AND WHITTINGTON PRINTERS EPSOM