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IGNITION DISTURBANCES

BY

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INTRODUCTION

This paper is a revision of one presented before the Institute of Radio Engineers at Rochester, New York, in November 1933, and explains in detail the origin of interference in the circuits of a typical battery ignition system. It supplements the author's paper "Electrical Interference in Motor Car Receivers," PROC. I.R.E., 20, p.674; April, 1932.

In discussing the suppression or reduction of ignition disturbances or interference in the operation of radio receivers it seems desirable to summarize what little is known or surmised about the nature of these disturbances and their sources. While theoretical analysis unsupported by experimental evidence will not, in general, be found a complete basis on which to proceed in the development of satisfactory means for the elimination of ignition interference, the lack in the literature known to the writer of any detailed treatment of the problem seems to him to justify the analysis which is here given.

GENERAL CONSIDERATIONS

It has been customary to analyze the response of any tuned antenna system to interference or strays in terms of the selectivity of the system and its acceptance of a band of frequencies falling within the side bands reproduced by the complete receiver.

In the analysis of the response to a spark transmitter, either as a desired or as an interfering signal, where the individual wave trains follow each other at very short time intervals, this procedure yields useful results.

However, with ignition interference, the ignition sparks occur at such relatively infrequent intervals that the disturbance from any one ignition cycle has disappeared before the following one begins.

In the case of an eight-cylinder motor running at 3600 r.p.m., only 240 ignition sparks per second are required, each one of which persists for only a few microseconds. Thus the disturbance, which gives rise to the radio interference, occurs within an extremely short portion of the ignition cycle, often in the form of a single discreet impulse and is thus wholly unlike the conventional spark transmitter.

With respect to the radio receiver itself, the time constant of the tuned antenna circuit may be of the order of 10×10^{-6} sec. Thus at the end of one ignition cycle, $\frac{1}{240}$ sec., any disturbance is reduced to $\varepsilon^{-\frac{10^6}{10 \times 240}}$ times its initial value, or, for all practical purposes, zero.

It is reasonable to assume that no auxiliary car circuit, such as a resonant wire, rod, or frame, has any greater time constant than the above. Therefore no circuit is likely to be present in the field of the disturbance which will sustain oscillations until the next spark occurs. Obviously, at low engine speeds, the possibility of overlapping of the effects of successive sparks is even further avoided.

In this case it is simpler to deal with the individual damped wave trains than to resolve them into equivalent carrier and side bands.

I shall therefore discuss the theoretical nature of the wave fronts produced by a typical battery-ignition cycle, and then summarize the logical methods of reducing the response in the receiver to these impulses.

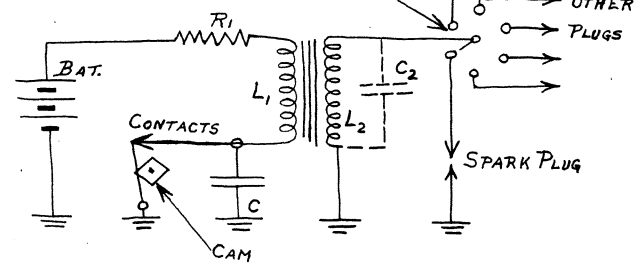

FIG. 1.

Figure 1 shows the portions of a battery ignition circuit which are usually considered in a superficial explanation of its operation. The constants which determine the interference transients include the obvious ones shown in the figure plus the distributed and lumped constants of all the wiring and the voltage-cur-

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TABLE I

PHASE	TRANSITION	CIRCUIT CONDITION	DIAGRAM	PARAMETERS	CURVES	CAR-RADIO INTERFERENCE	DISTANCE INTERFERENCE
	Contacts close	Zero current	Fig. 1.			No	No
1		Primary current increases	Fig. 1.	Fixed		No	No
	Contacts start to open		Fig. 2.		Fig. 3. Fig. 5.	No	No
2		Voltage increases across contacts	Fig. 2.	Variable K	Fig. 3. Fig. 5.	No	No
	Contact spark		Fig. 2.		Fig. 5.	No	No
3		Current transferred to condenser	Fig. 2.	Variable arc	Fig. 4. Fig. 5.	No	No
	Spark out	Steep L-T wave front	Fig. 2.		Fig. 5.	?	No
4		L-F oscillation	Fig. 6. Fig. 8.	Fixed	Fig. 7.	No	No
	Rotor gap breaks down	Rectangular H-T wave front	Fig. 8.		Fig. 9.	Yes	?
5		L-F oscillation H-F oscillation	Fig. 8.	Fixed	Fig. 9. Fig. 10.	Yes	?
	Repetition of above	Rectangular H-T wave front	Fig. 8.		Fig. 9. Fig. 10.	Yes	?
5a		L-F oscillation H-F oscillation	Fig. 8.	Fixed	Fig. 9. Fig. 10.	Yes	?
	Plug gap breaks down	Rectangular H-T wave front	Fig. 8.		Fig. 10.	Great	?
6		H-F oscillation H-T arc at plug	Fig. 8. Fig. 12	Variable arc	Fig. 11.	Great	Yes
	H-T arc goes out	Steep H-T wave front	Fig. 12.		Fig. 11.	?	No
7		H-F oscillation L-F oscillation	Fig. 6.	Fixed	End of Fig. 7.	?	No
	Contacts close						

NOTE:- L-T Low-tension
H-T High-tension
L-F Low-Frequency
H-F High-Frequency

rent characteristic of any arc or spark. These will be discussed in detail for each portion of the complete ignition cycle.

The analysis of the ignition cycle may be divided into separate periods or phases which follow each other in definite sequence. During two of these phases, the complete differential equations expressing the phenomena involve variable parameters, and a general solution is not practical. The results may be approximated qualitatively, however, by segregating portions of the circuit and by assuming that the audio, radio, and super-radio frequency components are confined to relatively simple parts of the complex circuit.

Having developed an approximate qualitative analysis, we may then estimate the magnitude of the interfering components, - at least to the extent of predicting the most troublesome ones.

IGNITION PHASES

In each complete ignition cycle there are eight distinct phases, between which the circuit parameters change abruptly. During these phases the parameters may also change slowly, as will be described. At each abrupt change the approximate analysis is transferred to a different portion of the circuit. Table I summarizes these changes.

PHASE 1

At the start of and during phase 1 no interference is produced since the primary current is then building up logarithmically at a relatively slow rate, limited by the inductance and the resistance of the primary circuit alone.

The other phases may give rise to radio interference and will, therefore, be discussed in some detail.

PHASE 2

Precisely how long phase 2 persists is rather uncertain since we have insufficient data on the voltage necessary to strike a spark across an exceedingly small gap thereby initiating phase 3. The explanation which is offered is, therefore, largely speculative, but leads to definite conclusions with regard to the wave fronts associated with the primary condenser circuit.

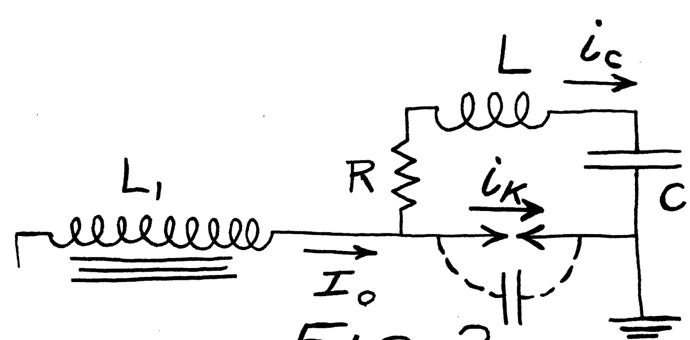

FIG. 2.

During phase 2 the current carried by the primary of the coil may be assumed to be constant, since it does not have time to change. Attention is, therefore, confined to that portion of the low-tension circuit between the coil and ground as indicated in Figure 2.

At the instant the contacts begin to separate, there is practically no voltage across them and before an arc or spark can exist, the voltage must be built up to a critical value. At the same instant all the coil current flows into the capacitance of the contacts and their mountings, as a displacement current, since the inherent inductance of the condenser circuit prevents an instantaneous building up of current in it.

If we could have geometrically perfect contacts 0.4 Cm. in diameter and separated by 0.0001 Cm., their capacitance would be approximately 100 mmf. As the gap is never uniform down to these small dimensions, the actual capacitance is appreciably less, but still large enough to be a factor in this study.

From the geometry of typical low-tension condenser circuits, it is estimated that their inductance may be between 20×10^{-9} and 500×10^{-9} henry. Let it be assumed that it is 100×10^{-9} henry.

If the contacts were instantaneously opened until their capacitance was 100 mmf. and thereafter remained fixed, the voltage across them would follow a damped radio-frequency wave of angular velocity

$$\omega \cong \frac{1}{\sqrt{100 \times 100 \times 10^{-21}}} = 316 \times 10^6 \text{ radians/sec.}$$

and $f \cong 50 \times 10^6$ cycles/sec.

During this time the low-tension condenser would receive no appreciable charge.

Actually, however, the capacitance of the contacts varies from infinity, when they are closed, to a negligibly small value, when they are opened an amount sufficient to prevent a spark, so that the oscillation starts at a relatively low frequency and rapidly but smoothly increases to a very much higher frequency than indicated.

The initial rate of separation of the contacts will vary from 2.0 to 25.0 Cm./sec., depending on the engine speed and the cam shape. The capacitance between the contacts will, therefore, vary inversely as these rates and inversely with the time measured from the beginning of the opening.

For a complete determination of the wave forms involved, a step by step method is indicated, integrating over increments of time (Δt) during which the contact capacitance is assumed constant.

The terminology used is as follows:

- R effective radio-frequency resistance of condenser circuit.
- L effective radio-frequency inductance of condenser circuit.
- C effective radio-frequency capacitance of condenser circuit.
- K variable capacitance of contacts and mountings.
- I_o coil current.
- i_c condenser current.
- i_k displacement current to contacts.
- t time.
- ω angular frequency.
- α attenuation constant.

The differential equation for the circuit is then:

$$\frac{1}{K}\int (I_o - i_c)dt = Ri_c + L\frac{di_c}{dt} + \frac{1}{C}\int i_c dt$$

or $\frac{I_o}{K} = R\frac{di_c}{dt} + L\frac{d^2 i_c}{dt^2} + \left(\frac{1}{C} + \frac{1}{K}\right)i_c$

Integrating, the current in the condenser circuit is:

$$i_c = \frac{I_o C}{C + K} + \varepsilon^{-\alpha t}(A_1 \sin \omega_1 t + B_1 \cos \omega_1 t)\Big]_0^{\Delta t}$$

where $\alpha = \frac{R}{2L}$

and $\omega_1 = \frac{\sqrt{\frac{4L(C+K)}{CK} - R^2}}{2L} \cong \frac{\sqrt{4LK - R^2K^2}}{2LK}$

and A_1 and B_1 are constants of integration. A new zero of time is taken for each integration.

The displacement current across the contacts is $I_o - i_c$ or

$$i_K = \frac{I_o K}{C + K} - \varepsilon^{-\alpha t}(A_1 \sin \omega_1 t + B_1 \cos \omega_1 t)\Big]_0^{\Delta t}$$

The voltage across the contacts is $e_K = \Sigma \frac{i_K \Delta t}{K}$

These currents and the contact voltage, until a spark passes, may be expected to approximate the form indicated in Figure 3.

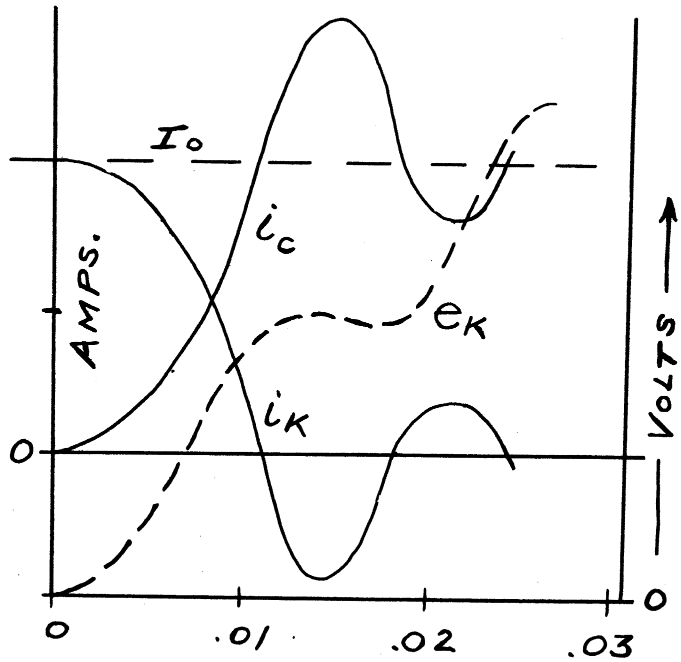

FIG. 3.

The interference, if any, produced by phase 2 will be discussed with that of phase 3, since it is of the same nature.

As is sometimes the case, if the voltage across the contacts does not build up to the critical breakdown value, depending on their separation, no primary spark occurs at all. Then the complete transfer of the current to the condenser circuit is accomplished as indicated in the figure. The total time required may be of the order of 0.02 to 0.05 microsecond. The major portion of the current is transferred in a fraction of this time with an exceedingly steep wave front. The following damped oscillation is at ultra-radio frequency.

Almost always, particularly at low engine speeds and with non-abrupt cams, the voltage wins in its race with cam opening, and a spark passes between the contacts. Phase 2 is then terminated and phase 3 begins.

PHASE 3

During phase 3, the contacts have usually opened to such an extent that the contact capacitance is negligible, particularly in view of the fact that the voltage required to sustain an arc is less than that to strike it. The voltage across the contacts is then determined by the arc characteristics of the contact material. For tungsten, which is ordinarily used, Anderson and Kretchmar*, give the voltage, current and gap relations as in Figure 4.

*University of Washington Research Papers.

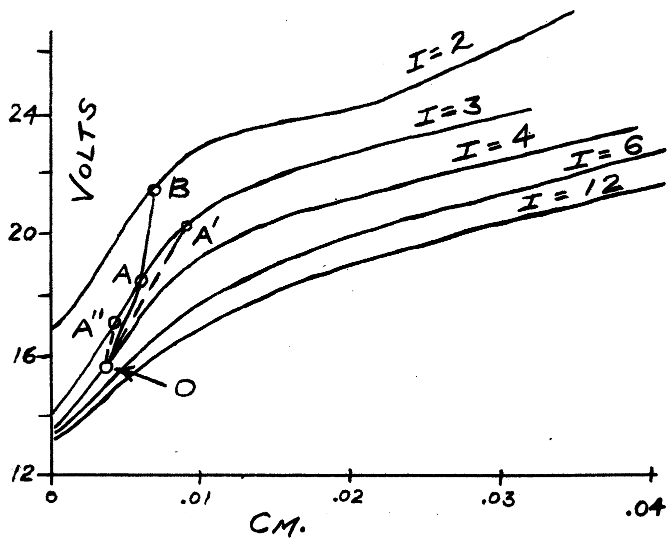

FIG. 4.

At the start of phase 3 the contacts are already open a small amount and a small current is flowing in the condenser circuit from phase 2. At a fixed engine speed the contact opening is approximately proportional to the time. We may, therefore, utilize Figure 4 drawn to a time scale for the applied voltage. The family of curves may also be identified by condenser currents rather than arc currents, the sum of the two being equal to the coil current.

When the arc is struck we are at some point O on the diagram. At a time Δt later we may be at point A. The voltage has increased at a rate $\frac{\Delta E}{\Delta t}$.

The differential equation for a step by step solution of the condenser current is

$$e_K = E + \frac{\Delta E}{\Delta t}\cdot t = Ri_c + L\frac{di_c}{dt} + \frac{1}{C}\int i_c dt$$

We may take increments of Δt small enough so that $\frac{\Delta E}{\Delta t}$ is constant and the solution for the current in the condenser is $i_c = \left(\frac{\Delta E}{\Delta t}\right)C + \varepsilon^{-\alpha t}(A_2 \sin \omega_2 t + B_2 \cos \omega_2 t)\Big]_0^{\Delta t}$

where α is as before, and $\omega_2 = \frac{\sqrt{4LC - R^2C^2}}{2LC}$ and A_2 and B_2 are the constants of integration.

Observing the initial conditions we may then solve for the current at the assumed time. If the calculated current change is not as assumed, we must correct our diagram by trial and error, but we may finally make an estimate of the proper change in voltage and plot it against the correct time on a curve.

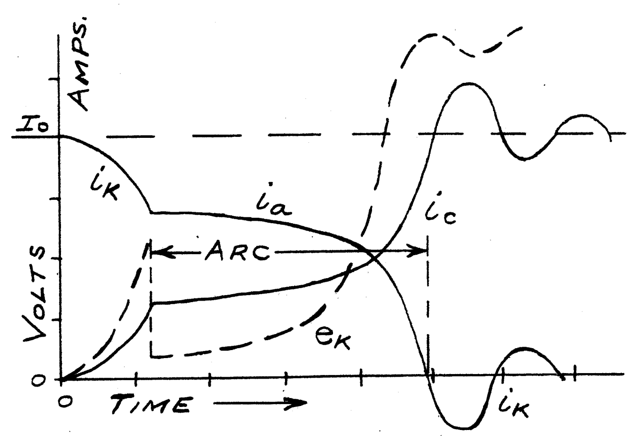

FIG. 5.

The complete solution is tedious but it is readily seen by inspection that, as the condenser current and contact voltage increase, they do so at increasingly rapid rates.

The voltage required to sustain an arc of less than 1.75 amp. is in excess of 100 volts.

Therefore, the current in the arc is sucked out and the voltage rises steeply. When this has occured the circuit oscillates as in phase 2 at a very high frequency determined by the now small distributed capacitance of the contacts and the inductance of the condenser circuit. This is rapidly damped and the total primary current is finally established in the condenser circuit.

An attempt to represent (not to scale) the complete spark and pre-spark phases is given in Figure 5.

All of this lengthy explanation is preliminary to the statement that whether a contact spark occurs or not, the coil current is finally transferred from the contacts to the low-tension condenser circuit with a very steep wave front. Any oscillations are at high radio frequencies, certainly well above the standard broadcast band. (0.5 to 1.6 M.C.)

The voltage wave front is also steep, but since the contacts are usually well shielded, and the maximum voltage is only a few hundred volts, this seldom gives rise to interference.

If, however, the condenser is not located within the distributor, the magnetic coupling of the condenser circuit to other circuits in the car may produce disturbing voltages as the result of the rapid change in current (say 0 to 4 amps.). The whole arc phase may cover a total time of perhaps 0.001 sec., but the most of the current is transferred during the last few microseconds. The voltage induced in any other circuit is, of course, $e = m\frac{di_c}{dt}$ where m is the mutual inductance of the condenser-contact loop and the circuit in question.

PHASE 4

During phase 2 and 3 the coil current was assumed constant. For phase 4 the effective circuit is as in Figure 6.

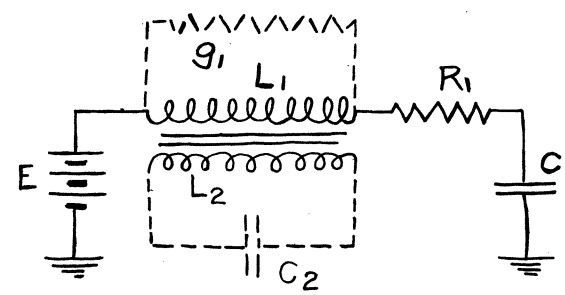

FIG. 6.

The primary current follows a logarithmically damped oscillation at an audio rate depending on the primary constants and those reflected from the open secondary thru a very high percentage of coupling between the windings. Figure 7 represents the case where no secondary spark occurs.

The frequency of this oscillation is usually between 2000 and 4000 cycles per second. The damping depends mainly on the coil losses other than the ohmic resistance of the winding.

If the secondary lead to the distributor were open, the secondary voltage would ordinarily rise to 30,000 or 40,000 volts, although at high cam speeds, which limit the time for the primary current to build up, it is often considerably less. The effect of even this high voltage is usually neg-

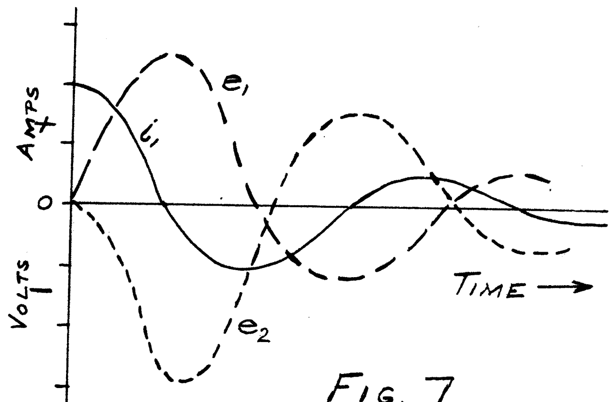

FIG. 7.

ligible because of its low frequency. Certainly there is no radiation at this frequency. If the antenna were coupled electrostatically to the high-tension terminal of the coil, there might be a slight response due to the induced transient at the tuned frequency of the first circuit in the receiver. This is rather a remote possibility.

There is probably no interference from magnetic coupling to the current in the primary circuit.

PHASE 5

The portion of the circuit to be considered during phase 5 is shown in Figure 8. It includes the constants of the high-tension cables, rotor gap, and spark plug. Actually the cable constants may be distributed, but as a first approximation they are here considered lumped.

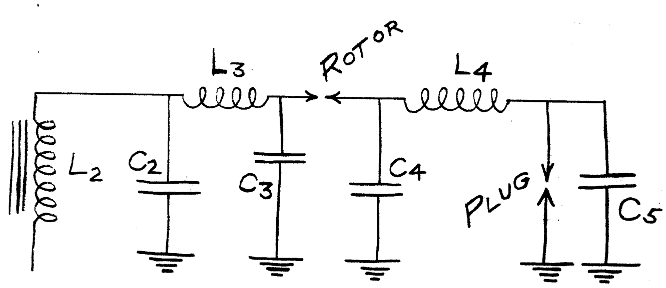

FIG. 8.

As the voltage rises at the secondary terminal of the coil L_2, capacitances C_2 and C_3 are charged at an audio rate with no appreciable drop across the cable inductance L_3. When the voltage reaches the breakdown value for the rotor gap, (depending on its length), a spark passes, partly discharging C_3 and charging C_4 to the same voltage. Except for the slight energy loss in the spark itself this would be instantaneous.

The circuits on both sides of the rotor gap respond to damped oscillations until the voltages are uniformly distributed at each end of the cables L_3 and L_4. The wave forms of the voltages across these several capacitances are shown in Figure 9 with corresponding subscripts.

Had the lead inductances and capacitances been uniformly distributed we should have had traveling waves along both of the cables with reflections at the terminals. During these oscillations both coil and spark-plug cables would be effectively open at each end, except for the slight lumping of capacitance at the coil terminals. Thus the lowest frequency at which the individual cables would oscillate would be approximately $f_1 = \frac{1}{2l_0\sqrt{LC}}$ where l_0 is the length corresponding to the formula for the familiar half-wave oscillation. In addition to this fundamental, all its harmonics, both odd and even, would also be present in decreasing proportion.

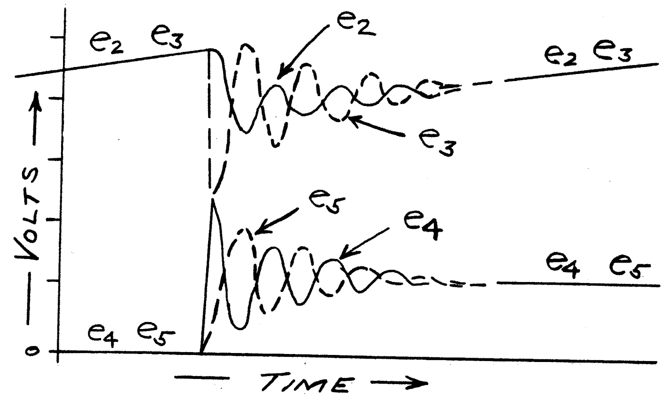

FIG. 9.

The capacitance and inductance of open high-tension leads spaced an average distance of two inches from ground are estimated to be

$$C = 4 \times 10^{-12} \text{ f/ft. and}$$
$$L = 300 \times 10^{-9} \text{ h/ft. respectively.}$$

The lowest frequency of oscillation in cable of this sort is

$$f_1 = \frac{450 \times 10^6}{l_0}$$

The cable connected to the coil would probably oscillate at a lower frequency because of the added capacitance of the secondary winding. The cable between the spark plug and the rotor would act practically by itself, with minor irregularities.

The capacitance and inductance of shielded 7mm. high-tension leads are estimated to be

$$C = 30 \times 10^{-12} \text{ f/ft. and}$$
$$L = 130 \times 10^{-9} \text{ h/ft. (ungrounded) or}$$
$$L = 65 \times 10^{-9} \text{ h/ft. (grounded)}$$

The fundamental frequencies for these conditions would be slightly lowered but not decreased in magnitude. In fact, because of the increased storage of energy in the larger cable capacitance the resulting spark would be "fatter".

As soon as the difference in voltage between e_3 and e_4 is again sufficient to break down the rotor gap, another spark passes. These cycles are continued until the voltage e_5 is large enough to jump the gap at the spark-plug electrodes. Phase 5 is then terminated and phase 6 begins.

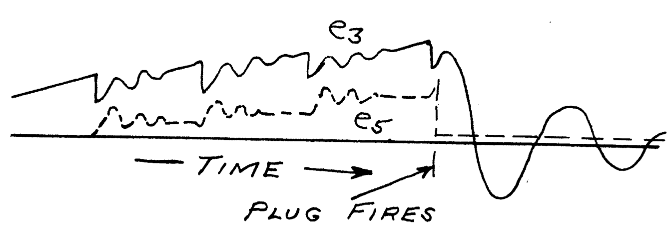

FIG. 10.

The voltages e_3 and e_5 (fundamental only) are indicated in Figure 10 for several successive rotor sparks terminated by plug breakdown.

PHASE 6

The spark at the plug almost short circuits it so that the voltage at its terminal drops almost instantaneously from, say, 6000 volts to only a few volts. During the first half cycle the rotor gap again breaks down and remains conducting, thereby making the circuit continuous from the plug to the coil.

A damped oscillation is now produced in the system which is much more violent than any of those preceeding it. Insofar as this oscillation is concerned, the cable is effectively shorted at the plug end and open at the coil end. Therefore, the frequencies present will be the fundamental

$f_1 = \frac{1}{4l_0\sqrt{LC}}$ and all of its odd harmonics.

This oscillation is accompanied by radiation from the length of the cable and also by the steep wave front at the plug which may be electrostatically coupled to radio circuits in the car.

These effects are by far the most serious of any during the ignition cycle. The radiation may directly affect an antenna on the car or at a distance. The steep wave front may produce oscillation in any auxiliary circuit on the car such as a choke rod, battery lead, poorly grounded hood, etc., to which it is coupled and which will radiate at the frequency to which it is tuned.

Suppose a circuit of lumped constants R, L and C to be coupled to the disturbance. The response is

$i = \varepsilon^{-\alpha t}(A \sin \omega t + B \cos \omega t)$

where $\alpha = \frac{R}{2L}$, $\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

and A and B are constants of integration. These depend on the coupling as well as upon the circuit constants. The circuit oscillates at the one frequency to which it is tuned.

If the circuit constants are uniformly distributed, the response to the same wave front is

$$i = \Sigma_n \varepsilon^{-\alpha t}(A_n \sin n\omega t + B_n \cos n\omega t)$$

where n depends on the type of oscillation, that is, half or quarter wave, as fixed by open or grounded terminals. Such circuits may then radiate to antennas on the car or at a distance.

The response in the antenna circuit to *one* of the damped oscillations, either in the high-tension cable or in an auxiliary circuit, is

$i = \varepsilon^{-\alpha t}(A_n' \sin n\omega t + B_n' \cos n\omega t) + \varepsilon^{-\beta t}(M \sin st + N \cos st)$

where s is the angular frequency to which the receiver is tuned.

The response in the car antenna by virtue of direct coupling to the steep wave front is $i \cong \varepsilon^{-\alpha t} M' \sin st$

Both of the above expressions have components at the signal frequency to which the receiver will respond. The damped oscillation of the auxiliary circuit may not have been within the usual side band region of the receiver, but because of the transient character of the wave, antenna current at the signal frequency is produced. The audio-frequency output of the receiver is determined by the envelope of the signal-frequency wave and by the transient response of the loud speaker.

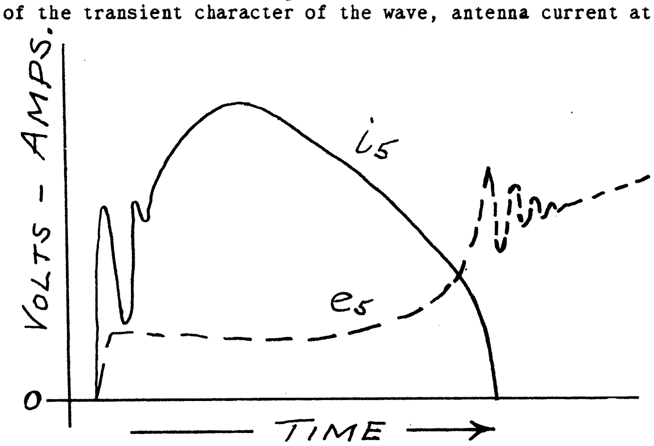

FIG. 11.

Before the oscillating current at the plug dies away the energy stored in the magnetic field of the coil and in the low-tension condenser establishes a comparatively steady arc current in the secondary circuit thru the plug to ground.

The rate of current rise is limited by the leakage inductance of the coil but it is essentially slow. Energy is then dissipated in all the circuits associated with this transfer and the current in the arc drops slowly and without interference components as indicated in the center portion of Figure 11.

However, the arc at the plug has a negative current-voltage characteristic, that is, the drop across the arc increases with decreasing current. The essential circuit diagram is shown in Figure 12.

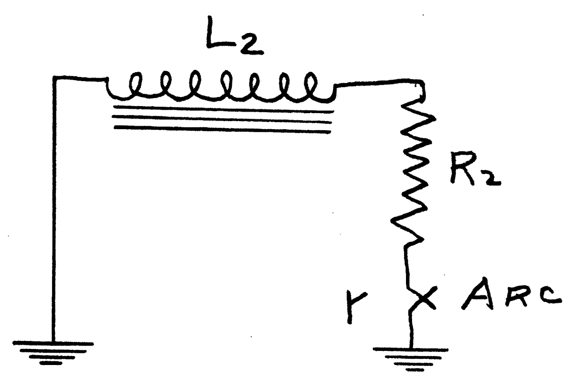

FIG. 12.

The secondary current dies out at an increasingly rapid rate as indicated in the latter part of Figure 11. The expression for the current is $i = I\varepsilon^{\frac{-R-r}{L}t}$ where r is the effective arc resistance which increases for small currents. Under certain plug conditions the current and voltage wave fronts are quite steep but it is very probable that the effects in the cable system are minor compared to those during the formation of the spark.

PHASE 7

When the high-tension arc goes out the cable is effectively open at plug, coil and rotor. These separate cable sections oscillate at the frequencies and with the damping found during rotor breakdown until the voltage is uniformly distributed along each section. However, since the wave front is not as steep as during breakdown, the effects can not be as great in magnitude.

After the arc goes out the remaining energy in the complete coil system produces a low-frequency damped oscillation of the same nature as in phase 4 but at lower values of current and voltage. Since these oscillations are at audio frequency, no further interference exists. Following phase 7, phase 1 is repeated.

SUMMARY OF INTERFERENCE SOURCES

Table I summarizes the interference phases discussed and gives references to the circuit diagrams and curves. The effects are important in the following order:-

1. Quarter-wave oscillations along the complete high-tension cable producing radiation.
2. A rectangular wave front of voltage at the spark plug which may induce oscillations in car antenna or auxiliary circuits coupled thereto.

3. Half-wave oscillations along the separate plug and coil cables producing radiation.
4. A rectangular wave front of voltage at the rotor gap which may induce oscillations in other circuits.
5. A steep wave front of current in the low-tension condenser circuit.

IGNITION INTERFERENCE SUPPRESSION

The most common method of reducing ignition interference is, of course, the use of spark-plug and rotor resistor type "suppressors". These resistances slow up the initial discharge of capacitances associated with the gaps and thereby reduce but do not eliminate the steep wave fronts. They also reduce the value of the gap currents and more or less effectively eliminate any oscillations in the high-tension cables.

If the car antenna or an auxiliary circuit is electrostatically coupled to the voltage at the spark plug, the suppressor is not a cure-all. If the suppressor has appreciable capacitance, either between its own terminals or to ground, there is still a sharp voltage wave front when the plug fires and an additional possibility of interference from the impulse discharge of the capacitance limited only by the low resistance of the arc. The resulting high current may be magnetically coupled to other circuits on the car.

The interference may be kept low by reducing the coupling from the sources of the disturbances to all other circuits and semi-isolated masses of metal. It is not sufficient to prevent direct coupling to the antenna. Inadequately grounded shielding of high-tension or car antenna cables may act as auxiliary circuits and should be avoided.

By-pass condensers with short sturdy leads may be used for effectively grounding circuits which can not be directly grounded.

The best method of interference reduction is the segregation of circuits. If all the high-tension leads and the distributor could be placed under a shield, well spaced from the leads, and well grounded at all its joints, radiation and electrostatic coupling would both be eliminated.

Some progress has been made in the use of band-pass antenna filters designed to prevent all voltages outside the desired band of frequencies from reaching the tuned antenna coil of the receiver. These filters do not eliminate components already existing in the pass band but reduce to some extent the impulse excitation of the first tuned circuit in the receiver.

The satisfactory reduction of ignition interference obviously depends on the proximity of the antenna to the car and the sensitivity of the receiver. Suppressors are said to be completely effective for reducing the radiation to conventionally located antennas for home receivers. Many standard-band receivers have been installed on cars having carefully located ignition systems where at the most only a single suppressor in the distributor lead was required. However, these same cars may have been bad radiators in the ultra short-wave bands. The final outcome, if all classes of service are to be protected, is up to the car designer.

DISCUSSION

As was indicated briefly by Mr. Curtis, the methods for reduction of the interference with radio reception commonly used in automotive ignition apparatus might or might not serve usefully to suppress interference in other frequency bands than the American broadcast band. Discussion on this point has been provided by Mr. H. A. Wheeler and Mr. L. C. F. Horle both of whom reported the making of measurements of the tendency toward interference of automotive ignition equipment in the high frequency and ultra-high frequency bands up to 70 megacycles. In both of the reported investigations in the high-frequency bands, the measurement of the tendency toward interference was made by the determination of the receiver operating conditions required to give a known peak voltage within the receiver circuits when the antenna of the radio system was placed within the interference field closely adjacent to the automobile. In the case of the data reported by Mr. Wheeler, which is reproduced in Figure 13, the values there given are determined from the degree of amplification in the radio receiver required to give a certain fixed peak noise output voltage across the speaker coil of the measuring receiver; while the data reported by Mr. Horle relates the high-frequency amplifier grid bias and hence, something closely approximating the logarithm of the amplification of the measuring receiver to the fre-

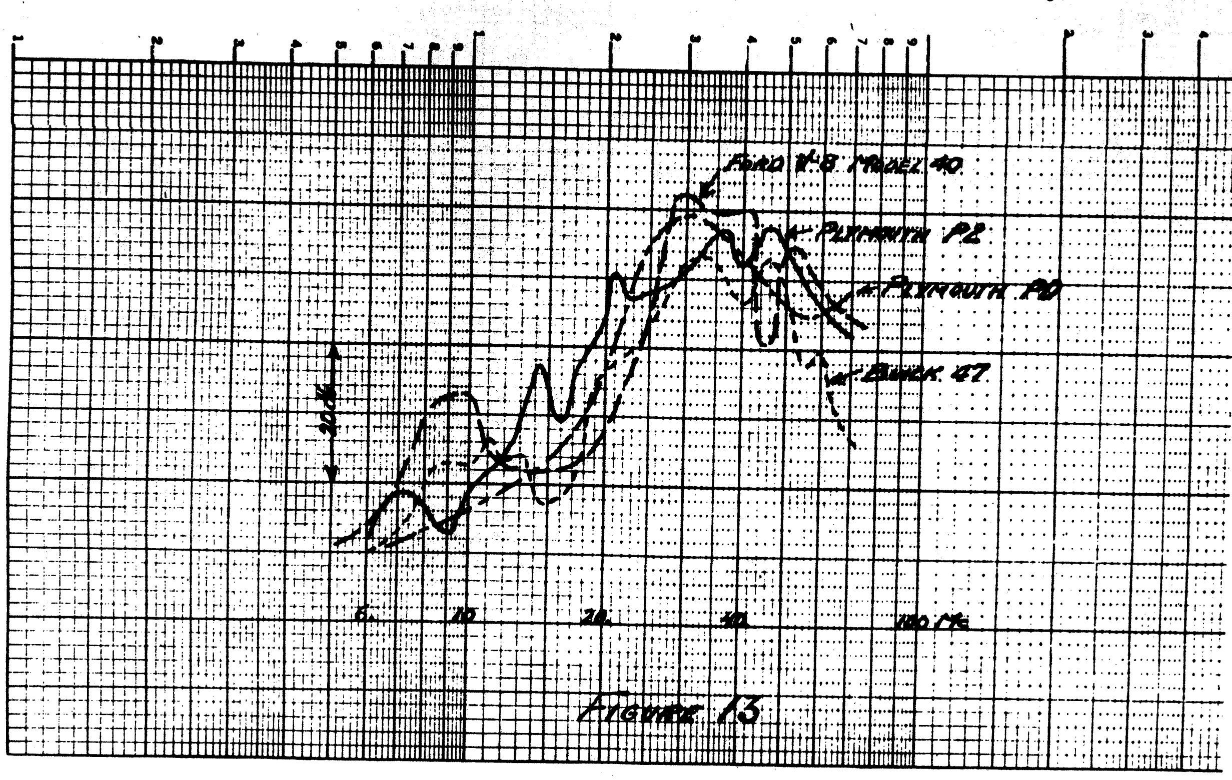

FIGURE 13

quency of measurement for a given peak noise output at the high-frequency amplifier output terminals. This data is shown in Figure 14. It is of interest to note in both cases that the interfering field intensities appear to be far higher in the high-frequency band than in the usual broadcasting band. This, it is believed, follows quite logically from Mr. Curtis' analysis of the phenomena operating in conventional ignition systems, and, most importantly, points to the need for especially careful consideration of whatever suppression means are to be employed if the frequencies above the normal broadcasting band are to be protected from ignition interference.

It will be observed from the Figures 13 and 14 how definitely the high frequency interference may be expected to operate against satisfactory radio reception in those bands commonly used for international broadcasting. It will be noted also how relatively great is likely to be the interference experienced in the 30 to 42 megacycle band within which already considerable aural broadcasting is being done in the United States and in the upper reaches of which doubtless far more will be done in the next few years.

While no spacific data was offered to the point, it was reported that some, but limited, experience indicates that the use of conventional resistance suppressors at the spark plug terminals and distributor terminals, while being very effective for the elimination of interference within the broadcast band, serves most indifferently, if at all, for the elimination of the interference in the higher frequency bands; thus, further emphasizing the need for the careful analysis of ignition circuits, such as are suggested in Mr. Curtis' paper, in order that the tendency toward interference may be reduced at its source, and the possible need also for the development of suppression devices which will be effective in the high-frequency bands as well as the low-frequency bands.

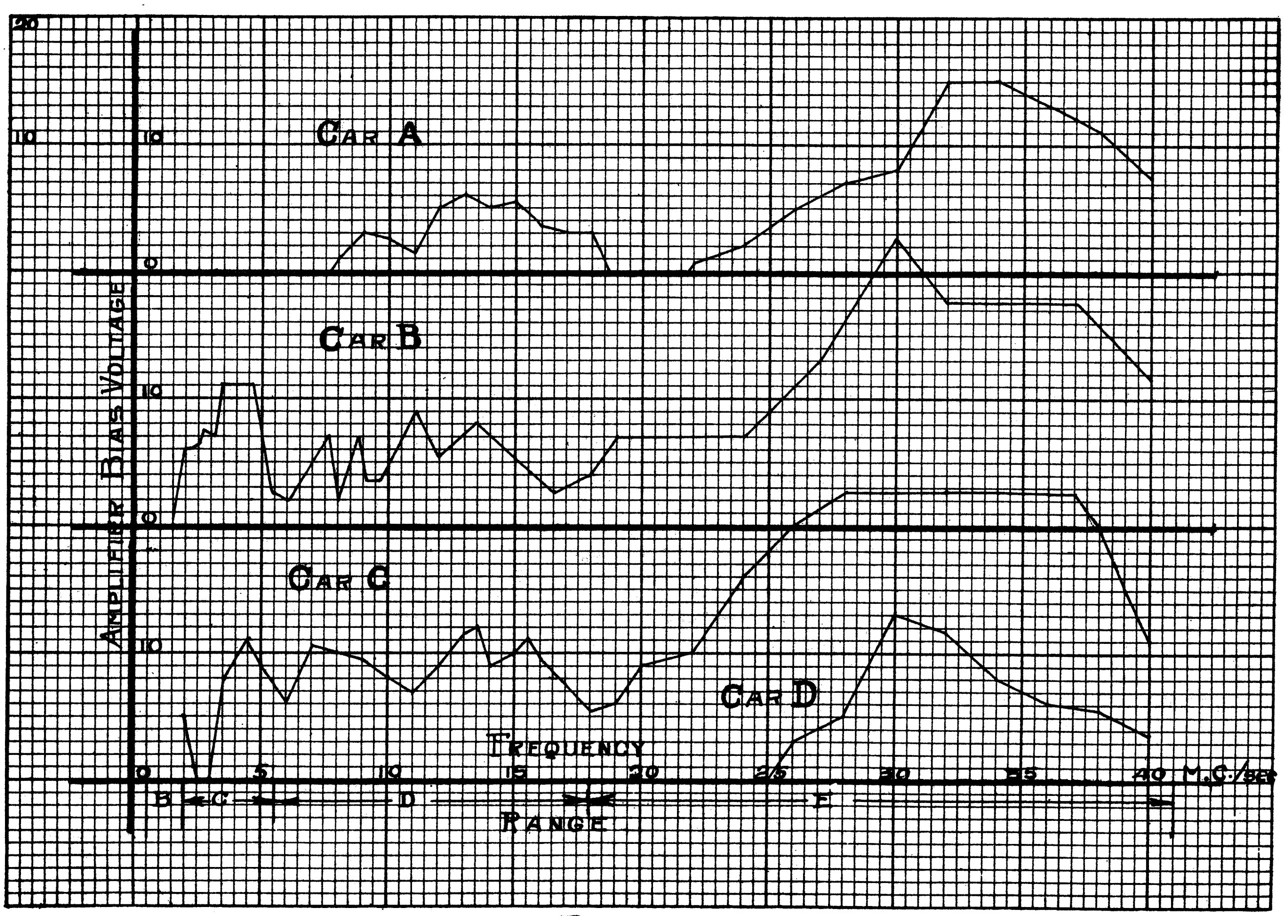

Figure 14.

BOOK REVIEW

MAKING A LIVING IN RADIO

by

Zeh Bouck

If "Making A Living In Radio" contributes nothing else than a removal of a veil of hallucination enshrouding the field of radio, it is worthy of publication. Radio is shown to be a cold, hard, practical field of a highly competitive nature in which the bonanza fruits of its early inception are bygones and wherein only fruits of difficult attainment remain - as in other stabilized, highly competitive industries.

Though the treatment is necessarily brief, the phases of servicing, operating, engineering, administration, sales, entertainment and writing are discussed with a cold-blooded and calculating introspection. The feeling of circumspection which it leaves with the reader is such as to discourage any except those who are intensely and genuinely interested.

Throughout the book the author stresses the fact that, as in any such competitive field, the need for as good an education as personal circumstances will permit is an ever growing one - regardless of what phase of radio the reader may contemplate choosing for his vocation. Certainly if one will heed its "road-markers" of circumspection, he will have traveled a long way towards "keeping his feet on the ground".

Lloyd West.