THEORETICAL INVESTIGATION OF DIFFERENT BOUNDARY CONDITIONS IN MAXWELL'S ELECTROMAGNETIC EQUATIONS.

Maxwell's equations describe the relationship between electrostatic and electromagnetic fields when these fields are a function of time. They are vector equations, and are the basis of present day electromagnetic theory. They are;-

$$\text{curl } E = -\frac{dB}{dt} \qquad \text{div } B = 0$$

$$\text{curl } H = J + \frac{dD}{dt} \qquad \text{div } D = p$$

The boundary conditions for these equations were determined from the static conditions which were normally observed to obtain, with a term for displacement current necessary to balance the equations. No account was taken of the possibility of variations within the structure of either magnetic or electrostatic fields as a function of time or space, and consequently div B was taken to be zero in all cases, and div D was taken to be a constant in all cases. That these assumptions are correct in the large majority of cases is self evident, but with techniques approaching higher and higher frequencies, and the expansion of our knowledge into those regions where relativity corrections become significant, it becomes increasingly more doubtful if the above Maxwellian assumptions are entirely adequate.

Investigation is therefore required of the effect of assuming other boundary conditions for these equations, such as,- div B = $F_{(T)}$ and div D = $F_{(t)}$, bearing in mind the real significance of such assumptions. Further investigation is required in working backward to find the necessary boundary conditions for electromagnetic wave motion having characteristics in line with observed phenomena, such as,- velocity of propagation being a function of the distance the wave has travelled.

Results of this investigation should be arranged and stated in such a form that they are possible of experimental confirmation or rejection. In other words the unique portions of the developments should be resolved into single terms around which suitable experimentation may be arranged.

ASSIGNMENT 2 S E C R E T

INVESTIGATION OF MECHANICAL FORCES ASSOCIATED WITH ELECTRON DRIFT OR CURRENTS IN SOLID BODIES.

Solids are generally so constituted that the atoms and molecules comprising them are in virtual contact and in addition, through electron exchange between atoms, substantial forces exist which hold the atoms in position while still permitting a certain degree of freedom. As a result of the electron exchange, many solids, particularly metals, find themselves with electrons which are free to move from atom to atom within the solid, even though the entire body remains electrically neutral. Under undisturbed conditions these electrons wander about in such a manner that the statistical effect of their motions outside of any appreciable region is nil. If, however, there is a net drift in any one direction, a current can be said to be flowing and the effect outside the region will not be nil.

Except under conditions of superconductivity, the drift of electrons within a solid is accompanied by an energy conversion of the driving electromotive force into thermal agitation and magnetic field. The net motion of each electron in the drift will be a function of the direction of the driving electromotive force and the magnetic field produced by the net drift of all the electrons involved, plus any external field which may be present. The energy necessary to get the electrons in motion is obviously converted from the driving emf directly into the surrounding magnetic field, but the energy given up by the moving electrons to the atoms amomg which they move must constantly be replaced by the driving emf, and appears as heat in the solid.

The conclusion follows that in any unit volume through which there is an electron drift, there should be a resultant force in the direction of the electron flow. Whether or not such a force will manifest outside of the total solid mass will depend largely on the configuration of the mass and the means whereby the driving electromotive force is produced. It is therefore intended that such forces be investigated from both a theoretical and laboratory standpoint, for various configurations, and means of emf production.

ASSIGNMENT 3

SECRET

MAGNETIC DOMAIN RESONANCE IN MAGNETIC MATERIALS

Magnetic materials are generally considered to owe their properties to rather small descrete regions having magnetic moments, and which are capable of reorientation under the influence of a magnetizing force. This reorientation is basically a mechanical process even though it may be at about molecular level. Consequently, a lag may be expected in the orientation of the domains when excited by a rapidly changing magnetic field, and in turn, it may be possible to induce a condition of continuous rotation of the domains by suitable selection of the frequency and configuration of the exciting field. Variation of the frequency of this exciting field and measurement of the magnetic characteristics of the material should lead to interesting results.

Furthermore, interesting magnetic properties may be developed by suitable heat treatment of samples while undergoing magnetic excitation at unique frequencies.

MAGNETIC WAVE MOTION IN MAGNETIC MATERIALS

In dealing with magnetic materials such as transformer cores it is generally assumed that the magnetic field in the core is precisely in phase with the magnetizing current in the exciting winding. For those frequencies with which ferro-magnetic materials are normally used this assumption may be sufficiently accurate for all practical purposes. However, when high exciting frequencies are involved, it may take the magnetic field in the core some appreciable time to become established. The mechanism by which such fields establish themselves is a subject requiring study.

When two coils are located on a common core but separated by an appreciable distance, the emf induced in the coil functioning as secondary may lag more than the usual 90° behind the phase of the alternating magnetizing current in the coil functioning as primary, by an amount corresponding to the time it takes for the field in the core to become established over the physical distance separating the two portions of the core involved. In other words, a longitudinal magnetic wave may be expected to propagate along the core between the primary and secondary coils. The reality of this condition requires to be investigated and a study made of the precise mechanism by which the field is propagated.

It may be possible to set up standing magnetic waves in a magnetic material by suitable selection of the material, configuration, and excitation frequency. The requisite conditions for the production of such waves should be studied, together with whatever alternative modes of oscillation may be possible of production

ASSIGNMENT 5

SECRET

INVISTIGATION OF POSSIBILITY OF MAGNETIC SINK

In the study of the static conditions of electricity and magnetism certain conditions are observed to prevail. It is generally assumed that such conditions are invariable and apply throughout the entire subject and are extrapolated into regions of new investigation. Generally, these conditions do appear to hold within the extrapolated region, but seldom is investigation carried to the point of determining if such conditions are the only ones which may prevail in this region.

This argument materializes when we consider the energy levels in magnetic fields in the light of considerations which we believe to be basic in nature, such as the law of conservation of energy, etc. There is no question that the magnetic field represents a certain quantity of potential energy which was placed in it when the field was established and is converted to some other form when the field collapses. In most electrical devices it is quite possible to trace entirely the energy cycle through the magnetic fields involved and to satisfy oneself of the various conversions involved. However, it is possible to devise several arrangements in which the energy cycle is not so apparent, and appear at first sight to be basic contradictions.

When a magnetic field exists it does so by virtue of some magnetomotive force, which may be either electric vectors in motion, or magnetic domains already established. In any case, at any particular part of the field there exists a certain energy level with reference to the level which would prevail if the field were entirely absent. If this energy level is changed, we may consider it in either of two ways. First, the total quantity of magnetic flux available in the region has either increased or decreased. Second, additional flux has been added in either the same sense or an opposing sense to the flux originally present. The net result of these two approaches is identical since they both lead to the same numerical answers, but they imply slightly different basic interpretations of magnetic theory.

Investigation is required along the line of the establishment of magnetic fields. Do the fields grow in their final position or do they move into this position from some other? Conversly, does a collapsing field decay or does it move away?

A further problem arises in the addition to or subtraction from the energy level of a magnetic field. Does energy added represent a proportionate increase throughout the field, or only along the vector direction of the field, and is it dependent on time in establishing its new level?

Other questions include; Can magnetic fields having common equi-potential planes be considered as independent fields? In other words, can a portion of a magnetic field be "walled off" by establishing even momentarily a surrounding equipotential plane? Can discontinuous magnetic vectors be established even momentarily? Can closed magnetic fields be established even momentarily independent of a separate magneto-motive force?

Answers to the foregoing questions will determine whether or not it is practical to establish a magnetic source or sink which can operate within a magnetic field alone, and without access to the initiating magneto-motive force. Such a sink is necessary if magnetic energy is to be converted directly and locally into some other form. The implications of such a sink are extensive, but there appears to be nothing basically contrary to the principle of direct conversion of magnetic energy into energy in some other form.

ASSIGNMENT 6

SECRET

SINGLE MAGNETIC POLES

Ordinarily, consideration of magnetic fields is based on the assumption that they are continuous and closed upon themselves, simply because we do not see in nature free magnetic poles. It is difficult to conveive of a basic reason why single poles could not exist, and it is highly probable that they do, under special circumstances. The most promising field of investigation would appear to be in the region of high frequencies because we know from our work with electromagnetic radiation that magnetic fields probably establish themselves with velocity c. Therefore, within regions readily accessible for observations we may be able to produce momentarily a region within which div B $\neq$ 0.

One possible method of accomplishing this, is to change rapidly the configuration of the field in a particular pattern. Another is to work through corresponding electric vectors which change with a particular pattern. A third method is to use standing longitudinal magnetic waves in a magnetic material, if such waves can be produced. Performance characteristics of wave guides combined with materials having non-linear magnetic properties could also be investigated.

The production of unit single magnetic poles might be a laboratory curiosity, but it is expected that they will show characteristics which will make them useful in the development of a communication means. This is particularly evident since the magnetic disturbance caused by a rapidly varying unipole would have different propagation characteristics in different directions relative to the field within which it might be located.

PROJECT MAGNET

It is proposed to investigate as many aspects of magnetic phenomena as possible with the object of determining whether magnetic sinks exist, domain resonances occur, and any correlations between them. 17

The work has been undertaken to establish certain theories on the extraction of power from the earth's field, outlined by W. B. Smith. In a very basic experiment performed by himself, with the assistance of J. Thompson, observations were made which would indicate the existence of the above mentioned.

In view of this a more practical laboratory arrangement was developed using a permalloy core as the focal point of the experiment.

Section A.

General Theory.

Referring to Diagram #1:

X and Y are undisturbed planes (app.)

MM and NN are undisturbed field vectors (app.)

a - core area l - core length v - al - volume

M - magnetomotive force (general term)

ϕ - vector field

R - reluctance of path (general term)

E - energy in region

μ - permeability of core (general term)

X - Y = L (length)

M - N = A (area)

$$M - \phi R \longleftarrow \qquad (1)$$

$$R = \frac{L-1}{A} \quad \frac{\left(\frac{1}{\mu a}\right)\left(\frac{1}{A-a}\right)}{\frac{1}{\mu a} + \frac{1}{A-a}}$$

$$= \frac{L-1}{A} \quad \frac{1^2}{1A - 1a + 1\mu a}$$

$$E = M\phi = \phi^2 R \longleftarrow (2)$$

$$E = \phi^2 \left(\frac{L-l}{A} + \frac{l^2}{(lA-la)+\mu v} \right)$$

It is assumed that if   is changed,

Then:

$$\Delta E = \phi^2 \left[\left(\frac{L-l}{A} \quad \frac{l^2}{(lA-la)+\mu_2 v} \right) - \left(\frac{L-l}{A} + \frac{l^2}{(lA-la)+\mu_1 v} \right) \right]$$

$$= \phi^2 \left[\left(\frac{l^2}{lA-la+\mu_2 v} - \frac{l^2}{lA-la+\mu_1 v} \right) \right]$$

$$= \phi^2 \left[\frac{l^3 A - l^3 a + l^2 \mu_1 v - l^3 A + l^3 a - l^2 \mu_2 v}{(l^2 A^2 - 2lalA + lA\mu_2 v + l^2 a^2 - la\mu_2 v + lA\mu_1 v - la\mu_1 v + \mu_2 \mu_1 v^2)} \right]$$

$$= \left(\frac{\phi^2}{A^2} \right) \left[\frac{l^2 v (\mu_1 - \mu_2)}{l^2 - \frac{2lal}{A} + \frac{l\mu_2 v}{A} + \frac{l^2 a^2}{A} - \frac{la\mu_2 v}{A^2} + \frac{l\mu_1 v}{A^2} - \frac{la\mu_1 v}{A^2} + \frac{\mu_2 \mu_1 v^2}{A^2}} \right]$$

If A becomes very large, the above reduces to:

$$\Delta E \simeq \left(\frac{\phi^2}{A^2} \right) v (\mu_1 - \mu_2)$$

$$\simeq B^2 v (\mu_1 - \mu_2)$$

<u>Experiment #1</u> (Based on above theory)

<u>Part A.</u> <u>To obtain characteristics of the core and winding.</u>

<u>Apparatus</u> (1) Test specimen - permalloy core reassembled from a Hammond Audio Transformer. It was wound with an exciter winding, bias winding and a third winding mutually at right angles (electrostatically shielded from the other two).

(2) Audio Oscillater 608A (G. R.)

(3) Impedance Bridge 650-A (G. R.)

(4) Cathode Ray Oscilloscope.

Apparatus connected as in diagram #2.

N. B. - pick-up winding centered such that it had 0 Mutual Coupling to other windings.

To find the variations of L with frequency in the exciter winding at 0 Bias. This winding had 49 turns of No. 28 D. C. C. wire.

Data

Freq. (C/S)	L (mh)
500	4.68
1,000	3.10
3,000	1.62
5,000	1.25
7,500	.98
10,000	.80
15,000	.62

l = length of core = 4.5 in.

A = Area of core = .187 in.

See Drawing #4 for curve.

Part B. Bias Winding Tests.

Apparatus - See the diagram #3.

N. B. Bias winding had 144 turns with R_{dc} = 3.8 ohms.

Procedure.

Holding frequency constant at 1,000 c/s., L was measured for changes in D. C. Bias current.

D. C. Current (ma)	L (mh)
25	33.0
30	30.0
40	23.0
60	10.2
80	7.7
90	7.0
100	6.0
110	5.8
120	5.4

See Drawing #5 for curve.

From theforegoing it is proposed to apply currents such that excitation will operate from the knee of the saturation curve to as near 0 Flux Density as possible. It is hoped to change the permeability sufficiently to realize the energy changes expressed in the theory.

Calculations for Exciting Current.

At the knee - $NI = \frac{(144)(100)}{1,000} = 14.4$ AT.

(referring to bias winding curve - Drawing #5)

Therefore $I_e = \frac{.707 \times 14.4}{49} = \underline{212}$ ma (peak)

49 / exciter turns

Exciter winding inductance at 1,000 c/s = $\underline{3.10 \text{ mh.}}$

Therefore Reactance $= \frac{3.10}{1,000} \times 6.28 \times 1,000 = \underline{19.5 \text{ ohms}}$.

Since R isnegligible,

Circuit Z = 19.5 ohms.

To obtain

212 ma. exciting current we must apply a peak to peak voltage of $\frac{212}{1,000} \times 19.5 = 4.13$ volts.

Part C. Experiment #1.

Apparatus was connected as shown in Drawing #6. The switching board shown here was used in conjunction with a special Milliwattmeter being designed in conjunction with this work. A separate section will be devoted to its operation. If any output was noted, careful study of the input wattage was to be observed. The Oscilloscope was used to keep a careful check on waveshape (pure sinusoidal voltage waves were applied to the exciter winding.)

Procedure.

(1) Operating at a frequency of 1,000 c/s and amplifying the Audio Oscillator output so that approximately 4 volts was applied across the specimen, careful watch was maintained on the output vacuum tube voltmeter for deflection. None was observed, either in line or across the earth's field.

Further tests were performed through the frequency range from 60 c/s up to 15,000 c/s, for all values of current in the Bias Winding up to 140 ma. Still no voltages appeared in this winding.

Experiment #2.

Part A.

As no indication of voltages being induced as a result of the earth's field were observed in Experiment #1, it was decided to reinstate the original experiment performed by W. B. Smith. Although at that time no actual figures were recorded, the basic characteristics of the experiment were exactly duplicated.

Apparatus.

In this experiment, a soft iron core of lower permeability was used and wound with just one winding on the yoke and a second winding placed (as in experiment #1) at right angles and shielded statically. Instead of a separate bias supply, the exciter winding was placed as the plate load in a 6L6 tube, utilizing the D. C. component of the current to achieve the bias level.

Procedure.

The Audio Input was applied at high level to the Grid of the 6L6. The 15,000 c/s frequency was used as in the original experiment. Still no voltage was detected in the second circuit in or out of the line of the earth's field.

Part B.

It was decided to determine all the characteristics of this iron specimen, similar to those carried out on the Permalloy core.

Using the same procedure as in Part B. of Experiment #1, curves were obtained for L vs. D. C. ma for various frequencies. Refer to graph on Drawing #7.

Relating the original experiment to the iron characteristics, it was noted that under no circumstances could the excitation have been changed sufficiently to operate from the knee of Saturation Curve down to a low value of flux.

This is quite apparent from a rough calculation of the Reactance at 15,000 c/s.

With approximately 50 ma (r.m.s.) through the plate circuit of the 6L6, the operating point would be less than half way up the curve. The Reactance of the exciter winding is $2\pi \times 15,000 \times 3.25 =$ <u>306,000 ohms</u>.

<u>Using</u> approximately 500 volts as a plate supply and about 210V on the screen, voltages were measured by means of the Cathode Ray Oscilloscope (which was calibrated previously). Measuring across a series 100 ohms resistance only .1 volt appeared.

An unbypassed cathode resistor (variable) gave fairly wide control of bias and variation of current).

However, this negligible A.C. component of current $\frac{.1 \text{ volts}}{100 \text{ ohms}} = 1$ ma did not satisfy the original requirements.

The maximum A.C. exciter current obtained using similar tube circuits (2 6L6's in parallel and the same supply voltage) came only to <u>11.4 ma</u>.

<u>Part C.</u>

It was decided to extend the foregoing tests downward in frequency so that higher currents could be obtained. However even with the larger excitation variations, no voltages resulted in the outer circuit.

<u>Experiment #3.</u>

Carrying the investigation further, saturation curves were determined for both the soft iron and permalloy specimens and values of μ plotted on them using log log paper.

<u>Procedure.</u>

A circuit was connected as in Drawing #8.

A spot galvanometer was placed in series with one of the windings (used as a secondary). In the case of the soft iron core a few turns were added as a secondary winding.

At each reversal of the switch, the galvanometer (now operating ballistically) deflects in proportion to the flux, transferred to the secondary winding.

Data and calculations were as follows:

I (ma)	Galvo Deflect (cm)	H (Oersteds)	B (Gauss)
7	.60	5.90	930
10	.95	8.45	1,470
20	1.80	16.9	2,790
40	3.60	33.7	5,580
60	5.30	50.7	8,210
80	7.15	67.7	10,500
100	7.70	84.5	11,900
120	8.38	101.0	13,000
140	8.70	118.2	13,500
160	9.20	135.0	14,750

Calculations for above:

$$H = \left(0.4\pi \frac{N}{L}\right) I = \left(.4\pi \frac{5,500}{3.22 \times 2.54}\right) I$$

$$B = \left(\frac{KR \times 10^8}{2N_s A}\right) \delta$$

$$= \left(\frac{2.56 \times 10^{-7} \times 4,800 \times 10^8}{2 \times 26 \times .25 \times (2.54)^2}\right) \delta$$

$$= (1,470)\, \delta$$

Where A = Core are (cm^2) K = Galvanometer Constant

L = Core length (cm) N_s = No. of secondary turns.

R - Total Resistance of Secondary δ = Galvo. Deflection (cm.)

Refer to Drawing #9 for Graph of the B, H. and μ relations.

Part B.

Determination of similar graph for permalloy.

Data for plotting saturation curve.

I (ma.)	δ (cm.)	H (Oersteds)	B (Guass)
1.0	.095	.016	100
2.0	.20	.036	212
4.0	.325	.063	344
5.0	.45	.079	477
7.4	.70	.117	742
10	.90	.158	955
20	1.30	.316	1,380
30	1.60	.475	1,700
40	1.75	.632	1,860
60	1.90	.950	2,020
80	2.0	1.270	2,140
100	2.1	1.580	2,220
120	2.15	1.910	2,280

$$B = \left\{ \frac{2.56 \times 10^{-7} \times 4800 \times 10^{8}}{2 \times 49 \times .187 \times (2.54)^2} \right\} = 1060$$

$$H = \left\{ \frac{.4 \times 144}{4.5 \times 2.54} \right\} I = 15.8I$$

N. B. These equations were arrived at as in the previous tests (Part A).

The graph will be noted in Drawing #9.

With reference to the data and a check with the graph, it will be noted that in two regions only does a wide change in μ exist. (a) At very low excitation levels (as flux is being initially built up).

(b) At regions beyond the knee of the curve.

In previous tests the latter had been thoroughly explored.

Part C.

Low excitations were then investigated, using the permalloy core in the circuit shown in Drawing #10. The tube was biased to cut off and driven to saturation.

Average primary current was measured = 0.39 ma. To determine the peak swings of excitation an oscilloscope was used to observe the voltage wave (see the waveform on diagram). By calculation, the conducting time (counting squares on the tube face)/cut off time ratio was determined from the waveform = $\frac{1.5}{20.5}$.

Therefore if r. m. s. value of current = .39 ma.

the peak value $.39 \times \frac{20.5}{1.5} = \underline{5.33 \text{ ma.}}$

H (for 5.33 ma. applied) = KI = $15.8 \times \frac{5.33}{1,000}$ = .0844 Oersteds

Using the Saturation Curve Drawing #9.

The corresponding flux density B = 510 lines /sq. cm.

μ in this region = 6050.

Conclusion.

The foregoing series of tests proved that the permeability of the core was being varied to its maximum extent under the limiting conditions of increased frequency. By completing the cycle as frequently as possible it was hoped to observe voltage in the output circuit. Still no indications of voltage were noted.

Note: It is believed that if a magnetic sink is possible, the method being employed is not capable of producing any power cycle. Therefore the net measured induced voltage is 0.

Further methods are being investigated to realize a positive increase in energy according to that developed in the theory.

Section B.

The Electronic Milli-wattmeter.

If small changes in watts are to be detected in the process of magnetic sink experiments, it will be necessary to have the type of wattmeter capable of detecting this. This would be used in the exciter circuit to ensure the power there was at all times known, so that any gain could be detected. Since the order of milliwatts is all that can be expected from the small experimental equipment, it was decided to use some tube system which would enable the multiplication of a voltage $\propto$ to the voltage across the test specimen, the voltage $\propto$ to the current through the specimen and also account for the phase angle (which should be approximately 87° assuming sinusoidal waves).

Part (a).

The first approach to this was arrived at by checking the mutual characteristics of a 6J5. It was noted that for small positive changes on the grid, the plate current was quite linear. Over this range the plate current was quite linear for plate voltage changes as well. See graph #11.

Therefore with the proper networks applying signals to the plate and grid circuits, it would be possible to obtain a multiplication of these two voltage changes (with the phase being taken care of, as instantaneous values would be multiplied).

It was, therefore, proposed to apply small voltages to the grid circuit $\propto$ to the current and have the plate circuit $\propto$ to the voltage across the circuit.

The first circuit developed is shown in Drawing #12. It was found very important that a fixed battery potential be applied at the cathode of the 6J5 and the plates of the two cathode followers be held at 150 volts regulated. To realize a net D.C. current half wave rectification was necessary at the grids. To obtain full power, the calibration curve must include a doubling factor to restore the half wave lost in rectification.

Initial tests for its operation were made as follows: (using the wattmeter without connection to the circuit to be tested).

(i) After 15 minutes of warming up, (without any applied signals) 0 volts was established between plate and cathode, using the voltage control.

(ii) The current control was set for 0 current in meter.

(iii) Applying a signal to input A, set 0 current with the voltage control.

(iv) Checked that with no signal at A and a small signal at B, 0 reading resulted.

(v) With both applied simultaneously, meter read the multiplied value.

A plot to check on the linear characteristic was then made as shown in the graph. (See Drawing #13).

In one plot one side was held at constant input and the other varied. In the other case the reciprocal condition was checked. Over most of the range it was found quite linear and definitely multiplied the values.

Part (b).

In testing this for wattage calibration in the network, one complication arose out of the attempts at direct measurements of power in the specimen itself. It can readily be seen in the Drawing #12 that with the phase relations required to operate on the grid and plate with simultaneous positive going waves, a phase inverter must be used as the voltage across the current resister is 180^{o} reversed from the voltage wave (owing to the necessity for a common earth through the network).

Besides this it was found that the cathode follower connection to the grid circuit lowered the input impedance to the point where the plate current was so small that it became difficult to obtain very accurate and stable readings.

The circuit under development at the present time is shown in Drawing #14. It is hoped that variations on this will produce the required wattmeter, sufficiently accurate for the experimental requirements.

Section C.

Domain Resonance Experiments.

General.

In substantiating the Twin Fabric Theories developed by W. B. Smith, it is necessary to determine beyond any doubt, the existance or non-existance of Longitudinal wave motion in the establishing and decay of flux through an iron path.

The following sets of experiments, using a small toroid of permalloy (approximately 2 1/8" diameter and 1/4" thick), are designed to discover whether any resonance conditions exist in the permalloy over a wide range of frequencies. If resonance or standing waves result, they can only have been created by a longitudinal motion (owing to the nature of the circuits used).

Also if flux does not follow the path around the core according to normal transformer concepts, then it could be concluded that only transverse motion is possible or that flux is created instantaneously (something hitherto not conceived of in nature).

Experiment #1.

This first experiment was to determine the most accurate means of measurement.

Test (a). With only a few turns wound over approximately 1 in. of the toroid's circumference, it was connected through a two way switch to the input of a SX42 Receiver. The output of a Signal Generator # Type 80 was applied via the switch through either the inductance to the receiver or directly to the receiver.

It was hoped by this to maintain a constant applied input and plot the changes of input as a result of the inductance of the coil on the toroid. The receiver output was connected to an Oscilloscope which was used as the amplitude measuring device.

This method of testing was unsatisfactory as resonance conditions resulted due to generator and receiver input circuits. They were definitely proven to be coil resonance variations and would mask the observations of core resonance.

(b) Placing another winding on the opposite side of the Toroid the specimen was then treated as a transformer. An identical input and output circuit was used as a comparison method Across the primary was placed (as well as the signal being applied) a 1N34 detector with bypassed μ Ammeter in series. The secondary had the same components across it.

Coil resonance conditions were still masking the results to be observed.

(c) Other methods were investigated but the first successful measurement system was the use of the 916A G. R. Bridge. The frequency range from 2 Mcs. to 28 Mcs. was covered in steps of 1 Mc. as a rapid check for change of reactance (using one winding only). This range was extended to over 50 Mcs. by reducing the number of turns from five to two. At no point was there any deviation from the normal linear reactance rise. Note Drawing #15. The slight waver about the straight line results from variations in balancing of the bridge and definitely not condition of resonance.

(d) This range was again swept more carefully - operating the receiver on broad band width and constantly riding through the frequency range (receiver tracking generator). Balance condition always existed on the bridge without deviation from the normal rising reactance value.

Both primary and secondary inductances were measured and also the total L (the two windings in series).

From this formula $L_1 + L_2 + 2M = L$

M could be readily arrived at. None of these values showed other than the gradual $2\pi fL = X_L$ increase.

(e) The 916A Bridge was not accurate down to lower frequencies so a scheme was devised whereby the range from 9.5 Kcs. to 950 Kcs. could be very quickly and accurately investigated for resonance.

Referring to the circuit in Drawing #16:

This was developed to take account of any phase deviation between primary and secondary windings of the Toroid transformer. If a 90° phase displacement resulted it would show the existance of a standing wave.

This circuit utilizes two 6AK5 amplifiers, To the grid of one is applied the primary input signal and to the grid of the other the secondary output. The outputs of each 6AK5 is applied via phasing condensers to the X and Y circuits of a Cathode Ray tube. A commoning switch is provided to enable application of simultaneous voltages to the two grids as a check that the networks are balanced. This is set to produce a straight line (as near 45° as possible). Then on opening the switch, the line should not become elliptical or circular unless resonance conditions are being approached.

The range of 9.5 Kc. to 950 Kcs. was covered completely by this method and showed constant straight line (0 phase difference between the two windings).

Further coverage was impossible owing to the C. R. T. limitations - resulting from the high frequencies applied (transit time of electron was about equal to the period of the half cycle).

(f) It is hoped to close the gap between 950 Kcs. and 2 Mcs. with a better Oscilloscope.