RADIO INTERFERENCE

from the

STANDPOINT OF THE CENTRAL STATION

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For

THE DEGREE OF ELECTRICAL ENGINEER

BY

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PREFACE

With the advent of the radio a new problem has presented itself to the Central Station. It has been necessary for the Electrical Engineer to change his methods, designs, and investigations to include the problems relating to the cause and effect of power transmission and distribution upon the broadcasting and receiving by radio.

The utilities have found it greatly to their advantage to carry on a very extensive investigation, involving troubles which are not entirely theirs, for the purpose of avoiding unjust criticism, and complicated public relations.

While experience has shown that the small percentage of the troubles are caused by the Central Station equipment, the assistance in eliminating interference and potential sources of trouble is more than offset by the good will of the public.

It is the purpose of this thesis to give a history of investigations, methods used and results obtained, in the eliminating of radio inductive interference.

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HISTORY

The first complaint of radio interference received by the Kansas City Power and Light Co. was in September of 1924. It was looked upon as something out of the ordinary. During the next four months a number of others were received, these coming from different persons, some who were experimenting with sets made by themselves, others, who were interested in the new phenomena. They complained of noise that was interfering with their reception. These complaints were investigated, but were not considered of great importance, until the last three months of 1925 when fifty-seven complaints were received. The cause of the troubles are listed in the order of magnitude in which they predominated: Electro-therapeutic apparatus used by physicians, interior troubles in complainant's house wiring or appliances, oil burner motors, street cars, trouble in complainant's sets, telephone ringing sets, noises disappeared or were imaginary, tree limbs in contact with primary lines.

The complaints have been very materially reduced by a systematic method of investigation, the cooperation of the local radio club and the education of the listening public.

PUBLIC POLICY

Since it is estimated that the use of radio has

added more than one half million dollars to the gross revenue from the lighting customers yearly, it is readily seen that the question of public policy plays an important part in the matter of handling radio complaints. Through the continued efforts of the Public Utilities during the past two years to eliminate interference and keep the public from being disturbed from real or imaginary troubles, many friends have been made and it has afforded the opportunity for the promotion of sale of Utility stock among its customers.

It is important then that the investigator not only be technically qualified for the work and familiar with the system, but also, a man whose personality will afford him the entry into all types of homes.

PUBLICITY

It is very important that the public be informed correctly regarding the many different sources of interference and the difficulty in locating the causes. The Public Utilities have recognized this fact and are taking the initiative in this work.

There are many ways in which the public may be reached. The newspapers, local clubs, broadcasting stations, individual listeners, all of these are available and they are also seeking advice and information.

Many attempts have been and are being made by

radio enthusiasts to pass legislation seemingly favorable to the amateur, but in reality very detrimental to everyone, and by the timely efforts of the Utilities, such action is being held in abeyance until such time as both sides of the problem can be given the proper consideration.

It is difficult to estimate the value of newspaper and magazine publicity from the standpoint of the Utility. The complaining public should know that its complaints are being taken care of conscientiously and that every cooperation is being offered them. However, experience has shown that unwise newspaper publicity, concerning service rendered to the public, will bring in many complaints that are unfounded. Personal visits followed up with a letter, giving a complete explanation with recommendations and suggestions, have proved to be the most satisfactory method of handling these complaints.

SOURCES OF RADIO INTERFERENCE

It is a well known fact that the smallest arc may cause interference. A loose connection in the house wiring may be the cause of imperfect reception for the immediate neighborhood. Battery charging and vibrating apparatus cause high frequency transients to radiate from the supply lines and cause radio interference. There are several types of motors in use on various household appliances, particularly, automatic apparatus such as oil burners and

refrigeration machines which have proved to be a great source of trouble. The most common source of trouble experienced, radiating from electrical appliances, is that of electro-therapeutic equipment used by physicians. They are equipped with a spark gap which radiates high frequency current over a large radius making it impossible to receive programs while they are in use.

Tree contacts, faulty lightning arresters, broken insulators, leaky insulation of all kinds are sources of trouble which may be experienced from power lines.

Probably the most common and the largest number of complaints received are reported to be due to transformers because of the hum which can be heard for some distance. This hum is produced by the vibration of the laminations of the iron core. It is a mechanical and not an electrical effect and does not cause radio interference.

HOW THE INTERFERENCE ORIGINATING IN ELECTRICAL APPARATUS REACHES THE RADIO RECEIVER

All electrical conductors carrying current are surrounded by an electro magnetic field. When the current in a conductor changes, the electro magnetic field also changes in a similar way and induces a voltage in any radio receiving aerial close to it, also, the electrostatic field surrounds all electric conductors at high voltage. A change in this electrostatic field also induces a voltage in the

aerial of any radio receiver which is close to the power wires.

Under normal operating conditions, on electric power lines, this electro magnetic and electrostatic field which surrounds the conductors does not extend more than a few yards from the power line. In some cases, however, where the change of current or the change in voltage is of a very sudden nature, called an electrical surge, a radio receiving aerial situated at a considerable distance from the power line may be affected. An electrical surge may travel many miles along a power line and produce a radiation which may be picked up on radio receivers.

The radio receiver aerial system, which includes both the aerial and the ground wire, should, therefore, be placed at as great a distance as possible from all electric power lines. In cases where it is not practicable to get far enough away from the power lines, the aerial should be run, as nearly as possible, in a direction at right angles to the power lines as the induction from the power lines is very much greater on aerials which run parallel to them. In no case should an aerial be errected above a power line in such a way that it would be possible for the aerial to come in contact with the power wire, in case the aerial should accidentally fall. Many accidents have been caused by aerials accidentally coming in contact with power lines.

CLASSIFICATION OF NOISES AND THEIR CAUSES

For the purpose of making a study of the subject it has been found to be advantageous to classify complaints in terms of noises. In general most complaints will fall into one of four large classes.

The first class is a smooth continuous hum experienced constantly, appearing as soon as the set is put into operation. This hum comes from the normal operation of house lighting circuits when installed according to old practice in the form of a loop. The hum is of a very low frequency and may be detected by placing the phones directly in series with the antenna and the ground. The second class is due entirely, and caused by radio receiving sets. They can be described as whislting noises and are familiar to every broadcasting listener. The third class is the crashing sound known as static which needs no description. The fourth general class of radio disturbances covers the field in which the Central Station is vitally concerned. It has been termed gurgling, frying, hissing, rumbling, etc. In this class fall most of the noises due to equipment and apparatus connected to the lines of the utility, whose operation is normal and cause no trouble on the lines of the Central Station. The company can in no way be held responsible for interference from this source. Included in this group is also the equipment and apparatus of the Central Station for which it is held responsible.

ENCYCLOPEDIA OF RADIO INTERFERENCE NOISES

Name of Noise	Interpretation of Noise	Cause and Operation	Duration	Effect
Buzzing	Sounds like a bumble bee flying. Sharp snapping usually accompanied by a flickering of lights.	Automatic oil burner usually having a spark plug for ignition.	Few seconds to several minutes. Present most of the time, may or may not stop at irregular intervals.	Blankets everything but local.
Humming	Sounds like an electric motor running.	Bell ringing set in Telephone Co. exchange.	Twenty-four hours a day.	Audiable pulsations intermittent with reception.
Crackling	Sounds like grease popping in a hot frying pan.	Primary circuit arcing in trees.	No consistent duration	Intermittent interruption of reception.

Name of Noise	Interpretation of Noise	Cause and Operation	Duration	Effect
Roaring	Sounds like the roaring of a fire under a strong draft.	Dr. electro-therapeutic machines.	Intermittent from one second to an hour.	Blankets distance and local reception depending upon location.
		Electric motors with commutators.		
		Defective connections in house wiring.		
		Passing street cars within distance of one block.	Occasional lasting few seconds.	Increasing and decreasing in volume fading out completely.
		Defective insulator.	Continuous	Blankets everything.
Popping	Sounds like pop corn popping in a closed kettle.	Defective grid leak.	Fraction of a second at a time, frequency dependant upon operation of set.	Interrupts continuity of reception.

GENERAL PROCEDURE OF INVESTIGATION

It is the general practice of the Utility to investigate all complaints of radio interference received. A preliminary investigation will usually determine whether the trouble is on the power lines or some other apparatus over which he has no control. If found to come from the power lines, the search is continued until the cause is found and eliminated. If from some other source the complainant is informed that the trouble is not caused by the power lines and the investigation is closed.

To avoid embarassing entanglements no information is permitted to be given out as to the source of the interference, when it is other than Central Station trouble.

In investigating radio interference complaints it is important that as much information be obtained from the complainant as possible. A questionnaire has proven to be very practical both in receiving complaints by telephone or to mail to the complainant. A suggested form is shown in exhibit 1.

Upon receipt of a complaint, by telephone or in person, the complainant is questioned in a systematic method in accordance with the questionnaire. He is requested to describe the noise complained of, giving the time of its

appearance, its variation in volume, and the maximum tuning point if it has any. If the complaint is received from the third person, in which case the details cannot be furnished, the principle points of the questionnaire are filled in after calling on the complainant.

Each radio complaint is acknowledged by letter, outlining briefly the salient points, based upon the information obtained from investigations thus far made.

When the call is made, the radio set is examined as to construction, make and general conditions, this being necessary to ascertain whether or not the trouble may be in the set and to familiarize the inspector with the particular set. The complainant is encouraged to discuss at length the trouble he has been experiencing. In most instances much valuable information not given at first is obtained. He is then requested to put his set in operation and to tune in the interference. Once this is done the investigator brings in to play his portable set, putting it along side of the other. An attempt is then made to tune the interference on the portable set. In cases where this cannot be done the trouble usually lies with the complainant's set. As a matter of courtesy an attempt is made to locate the fault and to recommend various changes which will correct his trouble.

If the interference can be tuned in, its

nature is carefully noted and classified. From the information a definite lead is obtained on the source of the trouble.

After the set has been thoroughly examined the main switch of the house is opened. If any appliances or wiring within the house itself are causing the trouble, the noise will stop, if not in the house the noise will be unaffected. When the source of trouble is found to be in the complainants house or in his set, he is acquainted with the conditions and where the trouble may be located. Interference may be expected from such sources as lamps loose in socket, loose connections in the wiring, loose plugs, faulty appliances, such as heating pads, curling irons, flat irons, motors, et cetera.

If the interference is established to be foreign to the complainant's house, the investigation from this point must, of necessity, be governed by the particular nature of the case.

Methods Used

There are two methods of procedure which may be used. The Directional and the "Hot" and "Cold" methods. The Directional method consists of tuning in the noise in question on the portable set and turning the loop antenna in the direction of the maximum interference. To be effective, the set should be taken to three or more different

locations in the immediate vicinity and readings taken, then by triangulation, the source of the trouble can be traced to a definite location. The Directional loop readings can not always be relied upon because of the fact that the trouble may be originating at some distance and is being carried out over the power lines. The loop will then pick up the fault in the direction perpendicular to the line at its nearest point.

The second, or the "Hot" and "Cold" method is the more reliable. It consists of selecting a point along the line under observation. The noise is tuned in, then reduced to a minimum so it can just be heard in the head phones. The set is then taken along the line, observing the strength of the signal at various points until it becomes a maximum, then continuing in the same direction until it again becomes a minimum or dies away. The location of the trouble is the point of maximum noise, or half way between the two vanishing points. Usually this method allows the source to be located within two or three spans.

By means of the two above methods most cases of interference may be located within a reasonable length of time.

Description of Apparatus Used

It has been established from experience that the best results are obtained in locating trouble with the

same type of set as that used for radio reception.

Several types of sets and equipment have been used by one Central Station with various degree of success. In the earlier stages a high resistance head set alone was used. One end of the cord was held between the moistened fingers of one hand, the other terminal was used as a directional aerial. This equipment is satisfactory for aggravated cases of trouble only, and for very short distances such as is experienced from broken insulators and arcing grounds.

The first complete radio set built for locating radio interference was one of the Colpitt circuit with two stages of transformer coupled audio amplification. The tubes were the UV-199 type and operated on dry cells all self contained. The aerial was wound around the outside of the case in the form of a loop. No shielding was used. The set was very susceptive to body capacity and good results could not be obtained. Later changes were made in the loop and condensers without improvement.

This set was finally discarded and a Radiola No. 26 was purchased. The set is entirely self-contained and consists of a six-tube super-heterodyne, catacomb revolving loop in the door and a built-in loud speaker. A jack was installed so that a pair of head phones could be used because it is not desirable to use a loud speaker for

tracing trouble. It is well shielded against body capacity and is easily tuned. It is very sensitive and susceptible to interference. It is sufficiently directional so that sources of interference may be determined within a few degrees. Results obtained from the use of this set have been very satisfactory.

WAVE ANALYSIS

While it is the general impression that Central Station equipment and lines are not the source of radio interference, a wave analysis of the system was made for the purpose of satisfying this condition. An oscillograph and a noise analyzer were used.

The oscillograph used was a portable Westinghouse, Three (3) Element Type.

The noise analyzer was a No. 2 Western Electric Co. used for the purpose of determining the frequency of harmonics present in power lines. It consists essentially of an inductance coil, variable condensers and binding posts. The coil and condensers form a fixed inductance and variable capacity which are connected in series, and when connected in the line to be tested can be used to produce a resonant circuit for harmonics, having frequencies from 100 to 2400 cycles. The variable resistance is a shunt across the terminals to which the line to be tested is connected and affords a means for regulating the volume of the noise

to be analyzed. Two of the switches provide for analyzing noises between the two sides of a metallic circuit or between both sides and ground, one for adding capacity and one for substitution a direct connection in place of the resonant circuit.

System Under Test

The turbo-generators at Northeast Power House are connected Y and grounded through a resistance. The primary side of the transformers at the substations are connected delta. The low side is connected Y with solid ground: the distribution system is three (3) phase, four (4) wire grounded neutral.

A series of tests were made at North East Power House, on a rural distribution circuit, on a city distribution circuit and at the laboratory.

The test of the generator is shown in Figures No. 490 and 491 which indicates the presence of harmonics up to the 27th. Oscillograms were taken on the secondary side of a substation supplied by a double transformation, delta-delta to delta-Y with grounded neutral. Figure No. 415 is the test made on phase wire to ground and shows harmonics present. This test was made without distorting any of the harmonics in any manner. Figure No. 416 is the result of a test made from phase wire to ground with a two microfarad condenser in series with the oscillograph element.

This test shows a prominent third harmonic and traces of a 9th and 27th harmonic. Curves were taken by connecting the oscillograph to the open corner of a delta connected bank of transformers. These tests shows the residual voltage of the circuit. The result being that the voltage was indicated to be mostly triple harmonic and 9th harmonic. In order to magnify the harmonics of the residual voltage a two microfarad condenser was inserted in series with the element of the oscillograph and the result was that a very distinct 3rd, 9th and 27th harmonic was shown. The result of these tests are shown on Figures No. 418 and 419.

Tests were made with the harmonic analyzer at the same locations and varified the results as obtained with the oscillograph. The following is the result of the Noise Analyzer tests:

Harmonics	Frequency	Setting	N.E.P.H.	12-1109	F-443	Lab.
3	180	0.1	B	A	A	C
5	300	.037				
7	420	.018				
9	540	.011	C	B	B	C
11	660	.007				
13	780	.0048				
15	900	.0035				
17	1020	.0026	C			
19	1140	.0019	C			
21	1260	.0015				
23	1380	.0012				
25	1500	.00095				
27	1620	.0007		C	D	

A - Largest volume
B - Next largest volume
C - Next largest volume
D - Next largest volume

The maximum harmonic on the system is the 27th, which has a frequency of 1.62 kilocycles.

Since the minimum frequency used for radio broadcasting is approximately 550 kilocycles, it is readily seen that no interference can be caused by the equipment of the utility when operating under normal conditions.

RECORD OF IMPORTANT CASES INVESTIGATED

The writer has been carrying on a very extensive investigation of radio inductive interference in the territory served by the Kansas City Power and Light Co. of Kansas City, Missouri. Following is listed the records and results of the most important cases investigated since October, 1925:

Total Number of Complaints Received	132
Number Investigated	126
Number Closed	67
Number not Closed	65

Of those closed the following are the causes to which the interference has been assigned:

Oil Burners (Automatic)	3
Electro Therapeutic Appliances	6
Tree Limbs in Primary Wires	4
Troubles in Set	9
Trouble from Motor in Building	1

Telephone Co. Bell Ringing Machines	4
Passing Street Cars	6
Trouble stopped prior to our call	18
Duplicates or false and unfounded	10
Trouble in House	6
TOTAL	67

ANALYSIS RADIO INVESTIGATION

Description of Complaint	The Cause	Results and Comments
10/13/25 - 3736 Indiana. Intermittent to continual crackling.	This trouble was located in the set by customer as faulty B batteries which were replaced.	Reported to the company that interference had stopped.
10/19/25 - 4221 College. A sharp snapping buzz at intervals accompanied by a flicker in the lights.	Cause was traced to an automatic oil burner.	The owner of this oil burner moved a few days after complaint was made and no further interference experienced.
11/4/25 - Armour & Virginia. Intermittent roaring noise. Very loud.	This interference was traced to an electro-therapeutic machine in a Doctor's office.	Dr. notified of trouble in his equipment. He refused to take any action. Referred to Government.
11/9/25 - 6911 Paseo. Intermittent crackling at night.	Trouble was traced to tree limbs in the street lighting circuit.	After trimming trees complainant reported the trouble cleared up.

Description of Complaint	The Cause	Results and Comments
11/9/25 - 47th & Mill. An intermittent roaring noise during the day and evening.	The cause was found to be an electric motor in a grocery store adjacent.	The complainant was notified of the cause and agreed to take the matter up with the grocery company personally.
11/16/25 - Edgerton, Kansas.	Complainant had a homemade superheterodyne and the trouble was found to be in the set.	This interference covered the town and was only heard when complainant operated his set.
12/21/25 - 7104 Montgall. Intermittent loud sputtering.	A faulty ground in the house lighting was found.	Complainant was advised to repair this, and later reported no more interference.
12/23/25 - 811 W. 38th. Occasional roar increasing and diminishing in volume.	This trouble was traced to passing street cars 1/2 block away.	K. C. Railway Co. was notified.
12/23/25 - 405 E. Armour. Intermittent sputtering.	Trouble was located in a faulty socket in complainants set.	This trouble being corrected no further interference was heard.
12/24/25 - Rockhill Manor. Continuous buzzing with occasional slight interruption.	General loose connections at the customer's main entrance switch and a jumpered fuse.	Stopped when the conditions were corrected.
12/28/25 - 2112 E. 73rd. Intermittent crackling.	Tree limbs in the primary were trimmed.	This removed the interference completely.

Description of Complaint	The Cause	Results and Comments
1/9/26 - 116 W. 69th. Intermittent humming and sputtering.	Opening complainants main entrance switch stopped the noise.	Complainant was advised to examine the house wiring for cause of trouble.
1/20/26 - 3951 Warwick. Continuous pulsating hum.	The cause was traced to the Tel. Co. building at 39th & Walnut and was from a bell ringer.	Engineers at the Tel. Co. promised to install devices to filter out the interference.
2/1/26 - 3128 McGee. Continual popping.	This was caused by a faulty grid-leak in complainants set.	Complainant told to change grid-leak.
2/20/26 - Indep. Mo. Continual roaring.	This complaint came through an anonymous letter that a certain mill on our lines was causing trouble.	No trouble was found and the complaint was closed.

CONCLUSIONS

In general, investigations have shown that the radio industry, the electrical manufacturer, and utility each have a duty to perform. The radio industry have produced sets and devices with inherent sources of trouble, which are sensitive and susceptible to and cause a large amount of interference.

The manufacturer must make such changes in his equipment and apparatus that will eliminate high frequency transients. The utility must be awake to the situation and give more attention to the constants of design and operation of its transmission and distribution systems. The radio industry which is responsible for the apparatus most effected must give close attention to the cause of interference.

Only through the well organized efforts of joint study and research by the allied industries and utilities is it going to be possible to obtain a solution to the problems of radio inductive interference with which we are now confronted.

QUESTIONNAIRE

DATE RECEIVED_____

1. NAME_____PHONE_____

2. ADDRESS_____FROM_____

3. TYPE AND MAKE OF SET_____

4. AERIAL OR LOOP_____

5. IF LOOP, WHAT DIRECTION IS INTERFERENCE_____

6. WHEN WAS INTERFERENCE FIRST NOTICED_____

7. WHEN DOES INTERFERENCE OCCUR: CONTINUOUS_____
DAY ONLY_____NIGHT ONLY_____

8. DOES IT SYNCHRONIZE WITH LIGHTING STREET LAMPS_____

9. NATURE OF NOISE: LOW HUM_____LIKE STATIC_____
ROARING_____HISSING_____

10. CAN IT BE TUNED TO A MAXIMUM_____AND AT WHAT WAVE LENGTH_____

11. IF SO, IS IT BROAD OR SHARP_____

12. HOW LONG HAS YOUR SET BEEN INSTALLED_____

13. HOW RECENTLY HAVE A&B BATTERIES BEEN CHARGED_____

14. GIVE NAMES AND ADDRESSES, IF POSSIBLE, OF ANY OTHERS IN VICINITY HAVING TROUBLE_____

15. DOES OPENING MAIN LIGHTING SWITCH MAKE ANY CHANGE_____

16. HAS ANYONE WHO IS COMPETENT EXAMINED YOUR BATTERIES AND YOUR SET RECENTLY: IF SO, WHAT DID HE ASSIGN TROUBLE: GIVE HIS NAME AND ADDRESS_____

_____

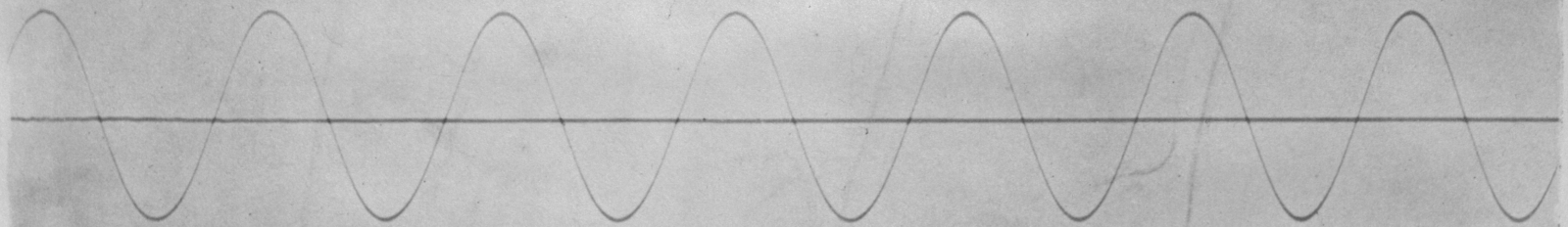
17. HOW MANY BLOCKS ARE YOU FROM NEAREST CAR LINE_____

18. ANY ADDITIONAL INFORMATION_____

T

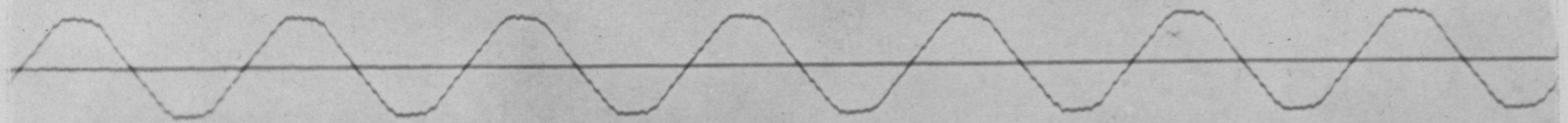
(Exhibit 1)

FEEDER No1337 AT N.E. STATION #490



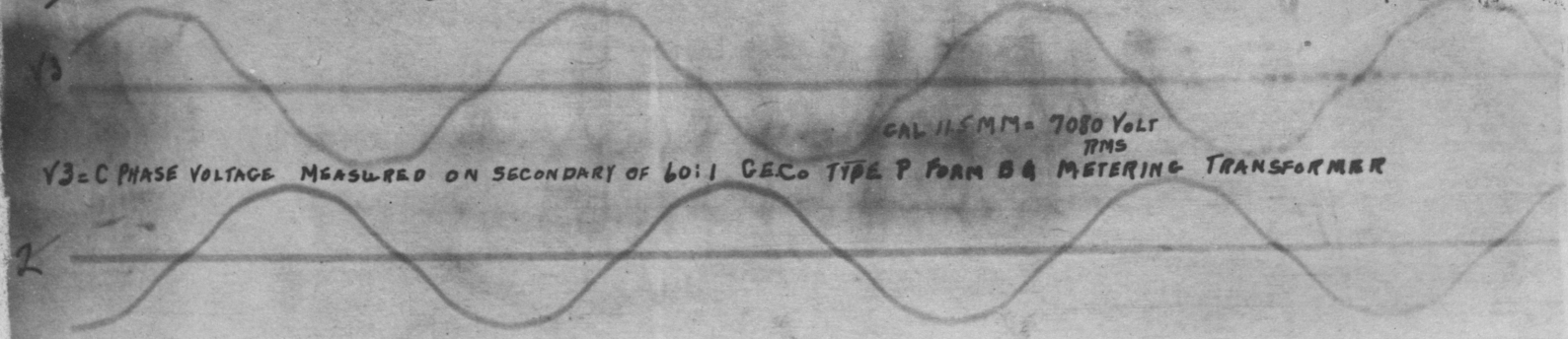
V_2 - Machines Nos. 1, 2 and 5 running. Instrument Transformer at open delta,
Neutral No. 5 closed. P.T. Ratio 120:1. Feeder No. 137.
2000 ohms in series. No condenser
Voltmeter reading 111.9V.

FEEDER No1337 AT N.E. STATION #491



V_2 - Machines Nos. 1, 2 and 5 running. Instrument Transformer at open delta,
Neutral No 5 closed. P.T. Ratio 120:1 Feeder No. 137.
8 ohms in series. 3-2 mfd in series
Voltmeter reading 111.9V.

CIRCUIT 12-1108 - POLE #5 HOLMES PARK 415

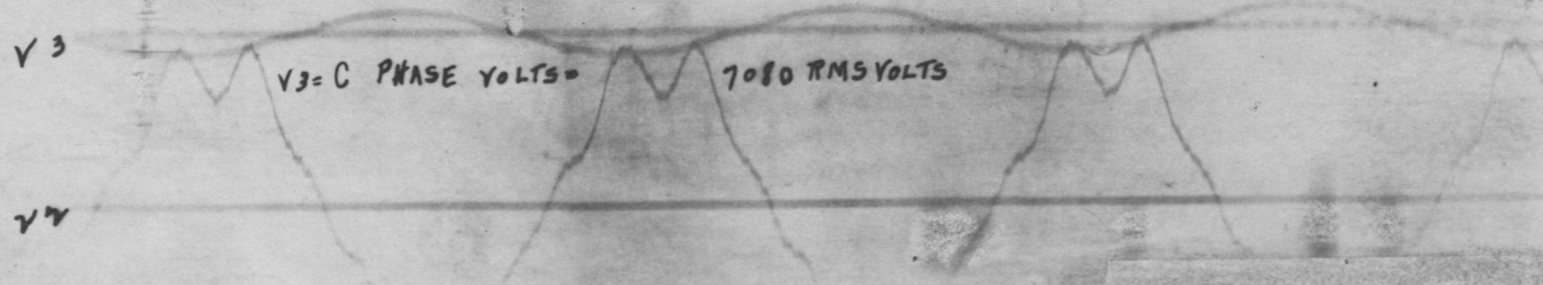


V3 = C PHASE VOLTAGE MEASURED ON SECONDARY OF 60:1 C.E.Co TYPE P FORM B Q METERING TRANSFORMER

V2 = A PHASE VOLTAGE - MEASURED ON SECONDARY OF 60:1 C.E.Co TYPE P FORM B Q METERING TRANSFORMER

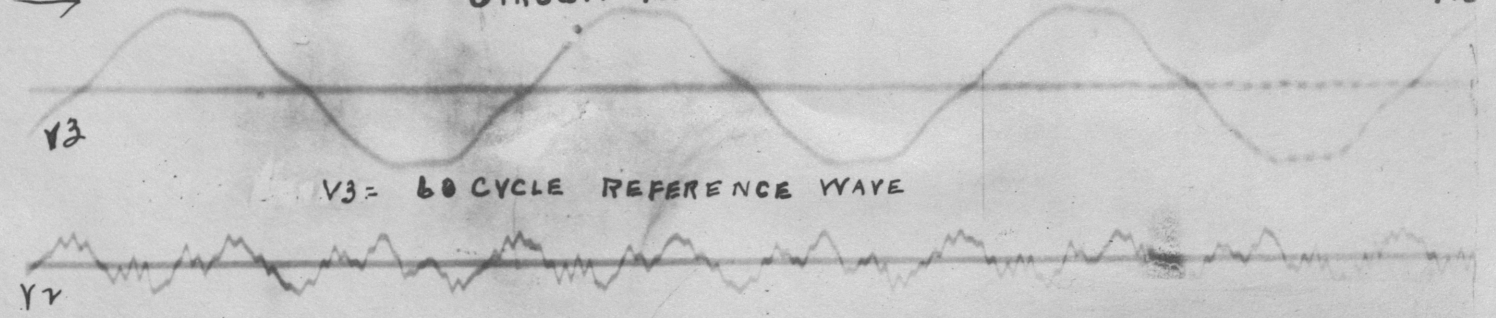
V1 = B PHASE FAILED TO EXPOSE - B VOLTS = 7110 RMS VOLTS

CIRCUIT 12-1108 POLE #5- HOLMES PARK 416



V2 = A PHASE WITH 2 M.F. AND NO OTHER RESISTANCE IN SERIES WITH VIBRATOR. A PHASE VOLTS = 7097 RMS VOLTS

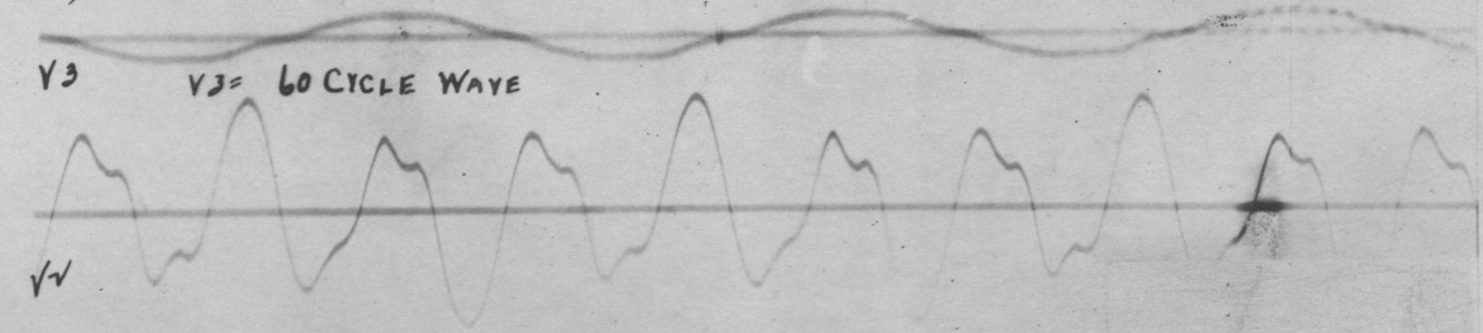
CIRCUIT 12-1108 - POLE #5 HOLMES PARK 418



V3 = 60 CYCLE REFERENCE WAVE

V2 = 2 M.F. IN SERIES WITH VIBRATOR ON OPENED DELTA, NO OTHER RESISTANCE IN VIBRATOR

CIRCUIT 12-1108 POLE #5 HOLMES PARK 419



V3 = 60 CYCLE WAVE

V2 = 100 OHMS IN SERIES WITH VIBRATOR ON OPENED DELTA CONNECTION. MEASURED IN RECORDING OF 60:1 PT.

BIBLIOGRAPHY

The writer had at hand reports of the member companies of the National Electric Light Association, General Electric Co., Radio Department Branch of Marine and Fisheries of Canada, The American Institution of Electrical Engineers and the results of tests and investigations made on the system of the Kansas City (Mo) Power and Light Co., together with the correspondence and conference with other engineers throughout the country who are interested in the same problem.