

9 October 1935

FR-1201
NRL Report No. R-1201
BuEng. Prob. I7-2

NAVY DEPARTMENT
BUREAU OF ENGINEERING

Report on
Investigation of Means to Reduce
or Overcome Effects of Static

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Number of Pages: Text - 9 Plates - 8

Authorization: BuEng let. L1-3/NP14(12-21-W8) of 21 September 1934.

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Distribution: BuEng (5)

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AUTHORIZATION

1. This problem was authorized by Bureau of Engineering letter L1-3/NP14(12-21-W8) of 21 September 1934.

OBJECT

2. The object was the development of means to reduce the effect of static in radio receiving equipment.

ABSTRACT OF TEST

3. The following systems were investigated:

- (1) The system covered by Mr. Haffcke's patent applications as were used during the initial demonstration.
- (2) A system that employs signal cancellation when received amplitude exceeded a predetermined value by a balancing out method.
- (3) A system of decoupling the signal circuits when applied signals exceed a predetermined value using Class "A" amplification.
- (4) A system of decoupling using Class "C" amplification.
- (5) A system wherein excessive amplitudes are converted into harmonics, which are subsequently filtered out of the signal circuits.
- (6) A system that employs an automatic amplitude control operating at radio frequency without apparent time lag.
- (7) A system employing a special tube which retains a normal gain characteristic for a relatively small range of control grid swing and converts the output energy for inputs larger than normal into harmonics which are filtered out by virtue of the receiver's selective circuits.
- (8) A system employing a limiter action at the receiver input. This system has not developed to a stage where any progress can be reported.
- (9) A system in which excessive voltages on an antenna system decouple the antenna from the receiver. This test has not been completed, but is a part of proposed plans.

Conclusions

- (a) The system first tried was obviously of no value, due to the lack of a constant "carrier" as found in a broadcast program. Due to this lack of "carrier" all inter-character noise came through apparently untouched and the system was abandoned for use with code reception.
- (b) The second system proved unsuccessful and was abandoned. Although a balance could be obtained and complete cancellation effected of both signal and static, segregating the signal from the static was found to be impossible, probably due to the change in wave form on one side of the balance, which would not cancel the wave form on the opposite side when attempts were made to cause an out of balance condition to exist until the input amplitude reached a predetermined value.
- (c) The third system apparently operated somewhat as expected, but, due to the rapid cut off of plate current when the decoupling grid was swung negative by the rectified current during inter-character intervals, the effect of this quick cut off or change in plate current would cause shock excitation of the following tuned circuits and the results showed but little change in the telephones, of the signal to noise ratio, and the idea was abandoned.
- (d) The fourth system calls for a change in the operating characteristics of the suppressor tube, and the bias was so adjusted as to cause plate current cut off when there is no signal. The system showed marked improvements over the former system (c) as the major part of the effect of the shock excitation during "no signal" intervals was eliminated. However, besides tuned circuits, there were critical values to be found by adjustment of the resistors R_1 and R_2 , as well as an adjustment on the sensitivity control on the set, all of which could not be predetermined and had to be made after the signal had been picked up. This was seen to offer a serious drawback and the idea was abandoned. This system was also applied by an adapter which inserted the circuits of the unit into the output circuit of the last IRF stage.
- (e) The fifth system was that of creating A.F. harmonics from all signals and disturbances of greater than a predetermined amplitude and showed very gratifying results, the main drawback to this system being that the unit was inserted into the circuits of the set just ahead of the audio system, and did not protect the 2nd oscillator from being thrown out of oscillation or "paralyzed" when extremely heavy surges arrived, and a small portion of the signal such as a "dot" would be missed before the signal would be restored again in cases where the sensitivity control on the set would be advanced to increase the volume of a very weak station. However, on such stations as GBR (Rugby, England) where the "sensitivity" control did not have to be too far advanced, and under conditions where the static signal ratio was not unusually great, this blocking or paralyzing action was not noted. The adjustments of resistor values in the circuits of the unit could be made fixed and it became necessary to bring the gain of the receiver up only to the point where the peaks of the signal wave were reaching the critical amplitude of the unit, above which harmonics are created, so that the high amplitude static surges would go well above, and subsequently be lost in the audio selective filter in the set. Care had to be used not to allow the signal amplitude to exceed by too great an extent this critical value, as otherwise the signal itself would reach well into the zone

where harmonics are created and thus a large part of the signal itself would be apparently lost also. To relieve this critical adjustment, the benefit of a rapid amplitude control operating at radio frequencies and without apparent time lag, inserted ahead of the present harmonic generating stage, was apparent. After further consideration it appeared that if such an automatic volume control could be developed it would in itself accomplish the desired results. This led to the tryout of the automatic amplitude control in the following system.

(f) This system of amplitude control is of such a nature that tuned circuits and variable resistors are not required for successful operation. The circuits of the tube are so arranged that above a predetermined amplitude, the output of the tube is such that there is no increase in output, this being caused by bringing about losses that are in direct proportion to the increase of the signal input above the critical value, never allowing the output of heavy static to be present at greater amplitudes than the desired signal. This was found to be quite effective and when the unit containing this system was inserted into the circuit in the last IRF stage, it was found that the paralyzing of the 2nd oscillator, such as was experienced with the system mentioned in (e) above, or when the unit was cut out of the circuit of the set, was eliminated, as was also the ringing effect in the selective audio filter, proving that the peaks of the static were levelled off approaching signal level in the radio frequency circuits without apparent time lag. After further consideration it appeared that in order to obtain the most satisfactory results it would be desirable to place the unit containing this system into the earlier circuits and thus avoid much of the shock excitation known to be existing in those stages upon the arrival of sudden heavy crashes, and accentuating the effect of the static in these earlier stages. The investigation of system #7 employing tubes now under construction will show the practicability of such an arrangement.

(g) Systems 8 and 9 are intended to cover an investigation of static interference reducing circuits ahead of the receiver itself. This work has not progressed sufficiently to permit any conclusions to be drawn.

Recommendation

(a) Although considerable progress had been made, it is not felt advisable to make any definite recommendation at this time for changes in existing equipment with the view of obtaining a reduction from static interference. Due to the magnitude of this problem and the fact that the most promising circuits have not yet been completely tested, it is recommended that the work continue until all seemingly practical circuits have been investigated.

METHODS OF TEST

4. All tests were made and adjustments changed while observing the effects on the cathode ray oscillograph.

DATA RECORDED DURING TESTS

5. All data were visual on cathode ray oscillograph and aural from head telephones, to date. The results of these observations are included in the conclusions as given in this report and in Plate 8.

PROBABLE ERRORS

6. The progress on this problem during the first four months was handicapped by a defective receiver, the abnormal condition of which was not apparent to the engineer assigned to this problem due to lack of familiarity with this particular receiving equipment. An investigation showed that 1 section of the selector switch was inoperative in the intermediate frequency amplifier and it was estimated that the sensitivity of the set was only possibly 10% of normal, or less. The increased sensitivity that a normal receiver would have given would have been a decided help in the problem as this difficulty existed during the period when static is at a minimum.

DESCRIPTION

7. System #1. (See Plate 1). In this system the tube ST is used as an amplifier being biased on the signal grid by R_2 , to the steep straight line portion of the E_g - I_p curve. If the amplitude of the received signal exceeds the critical value, the rectifier currents cause a voltage drop to appear across R_2 and a negative charge is impressed upon the suppressing grid and causes the tube to become non-conductive for the period of such high amplitudes.

8. For broadcast reception, where the carrier is always present, the rectifier circuits have a small current flowing which reduces the ST plate current somewhat and keeps it under control, so that when heavy surges arrive the plate current is merely reduced to zero and the following stages receive no further signal. The sudden reduction of plate current thus falls from the value at which the normal signal, being rectified, will allow to flow in the circuits of the tube ST, which is not equivalent to the "No Signal" value of the plate current; thus the change in I_p is not as great as though the same value of static were to be received without the presence of a carrier.

9. When tried for code reception, the absence of the carrier thus put the system into different operating conditions entirely than when used on broadcast.

10. System #2. (See Plate 2). The principle tried in this system was to cause an almost balanced circuit to tend to cut down high peaks.

11. The purpose of the battery was to cause one side of the balance to be inoperative until the signal amplitude became high enough to cause sufficient response in the plate circuit of that corresponding side of the circuit, to allow a "near balancing" out of signal in the output circuit.

12. Besides calling for critically tuned circuits, the possible changing of wave form made results indefinite and thus very unsatisfactory. Very little actual change on the relative noise to signal ratio was noted.

13. System #3. (See Plate 3). Here, the circuit looks similar to System #1 except that the charges placed upon the 1st grid of ST are now R.F. currents instead of A.F. components as with System #1. Otherwise, its action is similar. However, the same trouble encountered with #1 system was still present to a marked degree because of the sudden interruption of plate current when sudden surges arrived.

14. System #4. (See Plate 4). Tube ST is here biased on the signal (2nd) grid to cut off or slightly more than cut off. This permits "no signal" plate current to be zero until the signal applied on G₂ is great enough to cause the peaks at least to bring the grid G₂ into the working range of the E_{gs}-I_p curve, at which time the tube allows plate current to flow. If, however, the input voltage is above a predetermined amplitude, the rectified voltage across R₂ will cause G₁ to be charged negatively sufficient to cause E_{gc}-I_p cut off, thus maintaining silence in case of excessive surges for part of 1/2 a cycle.

15. Variation of R₁ through the range of from zero to the value to just cause plate current cut off and by obtaining the best point of resistance value of R₂, it was found that the results were at times really surprising, and better results were obtainable than with any of the former systems for code reception. However, the objection of requiring tuned circuits and several adjustments for the individual station signal were looked upon as serious drawbacks and the use of this system in the R.F. section of the set was abandoned.

16. System #5. (See Plate 5). Here, both tubes were used as detectors and the output of the system was taken off as audio frequency.

17. This is much the same as System #4 (see Plate 4) but now both tubes operating as detectors and the output of each being at audio frequency, the creation of audio harmonics being caused when the rectifier circuits cause sufficient voltage drop across R₁, which is impressed as an A.F. upon the 1st grid of ST causing one audio frequency to be imposed upon another but in opposite phase. This in turn brought about a conversion in the output of ST of that part of the audio signal above a predetermined amplitude, into harmonics which would be subsequently filtered out in the audio selective filter of the receiver. Thus the noise arriving at amplitudes in excess of the signal amplitude were kept out of the telephones and what little effect did pass through was of lesser volume than that of the signal.

18. In this system the resistance values of R₁ and R₂ could be set to a moderate volume and left alone, the only adjustment required being at the sensitivity control on the set to bring the amplitude of the desired signal up to just a little more than the point above which higher amplitudes were converted into the harmonics.

19. The drawbacks recognized with this system were mainly that circuits within the unit were tuned, and also that extremely heavy surges caused either preceding R.F. stages to become blocked or the 2nd oscillator would become paralyzed and a "dot" in the signal could be lost. In

plugging this system into the set, it was done in the 2nd detector position, the excitation for the "unit" being taken from the output of the 2nd detector, the R.F. component being utilized for excitation of the "unit".

20. System #6. (See Plate 6). This system of automatic amplitude control operated without appreciable time lag and practical tests indicate that the voltage amplitude, including both signal and static, is limited to not more than the critical value to which it is set. The simplicity of connections and the fact that tuned circuits have been eliminated are strongly in its favor, and practical tests show that the desired limiting action was present. The signal arriving at the input is passed through a resistor R_1 and thence to the grid above the critical value, the tube becomes a rectifier and the voltage drop across the resistor R_1 rises in phase with the signal wave and of opposite polarity. The difference between the signal wave voltage and the drop across R_1 being present on the signal grid allows only a limited rise in the charge upon the grid. However, this grid being now slightly positive causes a slight acceleration in electrons from the cathode and the internal impedance between the cathode and screen grid is lowered. The voltage across the resistor R_2 now increases due to increased current flow from the screen grid and the applied voltage present upon the screen grid drops proportionally, thus decreasing the electron acceleration from this element and in practically direct proportion to the acceleration caused by the slight positive charge present on the control grid. Thus the number of electrons arriving upon the plate remains practically constant on this half of the cycle.

21. On the opposite half of the cycle of the signal wave, the charge impressed at the input is negative and because the signal grid cannot rectify and allow current to pass through R_1 , there will be no voltage drop across this resistor and substantially the full voltage of this negative swing will be impressed upon the signal grid. However, as the internal impedance of the cathode to screen grid circuit is now raised, the voltage drop across R_2 falls and the applied voltage upon the screen grid is raised and the acceleration upon the electrons passing through to the plate is increased, and tends to again hold the charge upon the plate constant on the negative half of the signal wave cycle.

22. As all condensers are kept out of the circuit and the capacities within the tube are very low, the time constants of this system are practically nil as indicated by aural and cathode ray observations made when the system was applied to the intermediate frequency channels of the Model RAA receiver.

23. To operate this system with the present available types of commercial tubes, the "unit" was applied by plugging into the last IRF stage socket and inserting the circuits of the unit just ahead of the second detector's input transformer.

24. System #7. It became very evident that to further the tests along the lines of System #6, special design of tubes would be necessary with characteristics not found in any standard tube, such as extreme high amplification between cathode and 2nd grid, efficient shielding between 2nd grid and plate, and the 2nd grid of such construction as to allow high absorption of electrons and thus cause comparatively high screen current in proportion to the plate current.

25. Having no grid winder and welder available with which to wind the grids, it was necessary to improvise and substitute in order to test the theory.

26. The first tube constructed contained a heated cathode, a 1st grid of 60 mesh nickel, and a 2nd grid of similar material, and a plate from a standard 24 tube, the dimensions of the plate restricting, in a way, the spacing of the other elements, but at the first tests some idea was wanted as to just how practical it would be to use such a "first grid" as the main change toward the aim of high μ to the 2nd grid. Upon testing this tube it was found that the absorption and screening action was 100% until the electrons were accelerated by a positive bias to give them velocity enough to get through the holes in the mesh and pass on to the 2nd grid. At zero bias, the flow of screen and plate current was zero and not until a positive bias of approximately 1/4 volt was applied was any useful current found in either the screen or plate circuits.

27. The second tube constructed and tested was similar to the first with the exception that another grid of similar winding to that in a 27 tube was interposed between the control grid and the cathode, the object being to accelerate the electrons to such a speed that would enable some of them to pass through the mesh of the control (2nd) grid even when a slight negative bias was placed on it (control grid).

28. With a plus bias of 2 to 4 volts on the now 1st grid, speed enough was obtained to get good results as for screen and plate current, but due to the small spacing from the control (2nd) grid and the plate, the μ was much lower than was known to be wanted. However, another characteristic was noted which would become very useful and which has required the use of 2 tubes up to the present; namely, a quick return of the plate current to zero as the bias was lowered on the control grid and when the proper resistance (say, 50,000 to 100,000 ohms) is inserted in the screen circuit, the control grid charge being on the negative side at all times and drawing no grid current on signal voltages. (See Plate 7).

29. The same shape of curve could be obtained by changing the various voltages and running the control grid at zero. Then, of course, the grid would rectify and the input elements would act as a variable impedance across the input circuit and dampen the excess surges at that point and reduce the hangover due to shock, in the tuned circuits. However, by adjusting the bias on the grid to slightly negative, so that during periods of little or no signal, there will be no rectification and no flow of grid current, the strong surges will send the grid strongly positive and rectification will occur to dampen the circuit on the positive half of the cycle, and on the negative half of the wave the Eg- Ip curve will cause distinct harmonics to appear in the plate circuit of such order that the following tuned circuits will not respond. This occurs at R.F. The tubes built up to this time do not possess the necessary shielding to prevent direct capacity coupling through the tube, but have demonstrated on static tests that the desired characteristics can be made available with the proper tube arrangement and circuits.

30. Tube No. 3 was built using a grid from a 77 tube as a 1st grid, a screen grid from a 24 as a 2nd, a mesh of 60 as a screen near a larger diameter plate.

31. The cathode coating extended beyond the control region of the 1st grid and spoiled the action desired. However, it was found that the same character of Eg-Ip curve was preserved, and that the fall in plate current was the same on either side of the peak of the Eg-Ip curve when 100,000 ohms was inserted in the circuit of the 2nd grid. (Allowance being made for the electron leakage from the exposed section of the cathode.)

32. Tube No.4 is practically the same but with more careful construction and uses a shorter coated surface in order to cut out the electron leakage as experienced with tube no.3.

33. Tube No.4 contained the control and screen grids of a 24, an extra shield, and a standard 24 plate. The extra shield in this case was of perforated nickel and close to the plate, the idea being to use the tube in the R.F. circuits of the RAA with an adapter. The limiting action became very pronounced but the tube had to be used where the input swing would be that equivalent to the desired signal level in the last I.R.F. stage. This was expected because of the comparatively low Mu of this particular tube, high Mu being of secondary importance at this stage to good shielding and the ability to reduce to harmonics all voltages above the desired level; it being assumed that the harmonics will be of such order that the following stages will not respond readily, and repeat ringing will be missing in the A.F. filter and output of the 2nd detector, as well as affording protection to the 2nd oscillator from being blocked. It was realized that in order to adapt the tubes to earlier stages and retain the desired characteristics, extremely high Mu will be required, but it is a lot easier to work out the proportions required with a lower Mu tube and first get the desired Eg-Ip curve form and then increase the Mu to the desired point. That part alone is comparatively simple.

34. Tube No.5 was built more along what was believed to be the lines required for actual practice but before the tube was completed on the exhaust, an accident caused the filament to burn out and tests could not be completed. However, it was found that using screening for grids, except for cases where the screen is located too close to the cathode and when a positive bias is permissible, favorable characteristics can be expected.

35. Mr. Marshall of the Raytheon Products Corporation agreed to cooperate by building tubes to the Laboratory's specifications and samples were obtained. Tests indicated that these tubes were quite close to expectations for a tube to use in the detector (2nd) position, one which produced A.F. harmonics above a sharply defined critical value. The amplification factor of the tube within the useful input range was maintained the same as when a 224 detector was used. The signal gain up to the critical input value followed the curve of the same set with a standard tube. (See Fig.8 showing resonant overload curves for characteristics of both types of tubes.) The "cut-off" point of the special tube, however, was not clearly defined, but a constant level of output was obtained and held constant over a large range, after the dip in the curve was passed. This was in evidence when the A.F. filter was in the circuit. However, without the A.F. filter, the noise level went up as might be expected as A.F. harmonics were not rejected and the results were similar to when a 224 tube was used as the detector. With signals and natural static the reception was much more readable in the RAA receiver equipment with the special tube, when compared with a duplicate receiver with standard tubes throughout and adjusted to the best possible reception and using the A.V.C.

36. In trying to get equal results with this new tube in an earlier socket position in the set, the principal difficulty shown was that of internal capacity within the tube, the noise feeding through readily.

37. In order to remove this difficulty another grid, to be used as a shield and grounded through a condenser, is necessary and steps have been taken to obtain another lot of tubes possessing this feature. Furthermore, the signal input grid is to be of higher mu and make the tube more sensitive for the earlier stages.

38. The plans for an amplifier system for the purpose of modifying the static to signal ratio have been completed and a chassis is in the making in the shop.

39. New systems of noise suppression, by using the output of the amplifier mentioned in the previous paragraph, to control a variable impedance tube, which in turn may be made to affect incoming static impulses in various ways in the circuits of a receiver, to either null the signal, stop the heterodyne oscillator, or cut up a wave into relatively ineffective proportions, become possible. The fundamental principles of these various systems are being written up as patent specifications.

40. An effort is being made to cover the principle, believed to be unique, used in the construction of the special tube mentioned earlier, and the special circuits used to gain the results obtained, as the theory of the operation is somewhat radical, and to available knowledge has not been used heretofore.

41. System #8. Between intervals of building and testing tubes, a system utilizing an untuned amplifier and limiting stage, ahead of the set was tried but work has not progressed far enough to be able to report any real progress as yet. Investigation of this circuit is a part of future plans. A system such as this would permit the use of several receivers from the same pre-limiter.

42. System #9. Another system, not strictly a limiter, was tried wherein the untuned amplifier caused a discontinuous circuit between the antenna lead-in and the receiver upon the arrival of excess charges. The success of this system depends upon the provision of good selectivity ahead of the control which was not available at the time of test. Further tests will be made on this circuit.

43. Some objections may be sighted against tuning the pre-amplifier, such as the effects of shock excitation of a tuned circuit, but used in a pre-amplifier for this particular purpose it is felt that this shock excitation may prove to be an advantage, inasmuch as the action of the "cutout" tube will be enhanced and its operation more positive. Time constants for aural reception in particular may be ignored providing they do not exceed 1/1,000 second to possibly 1/200 second depending upon the speed of the transmission keying of "dots". Then, too, the grids of the tubes in the pre-amplifier may be so biased that when the danger of shock excitation is in excess, the grid will rectify and cause the load on the tube's input to dampen the circuit quickly and restore normal action more rapidly.

CONCLUSIONS

44. The system first tried was obviously of no value, due to the lack of a constant "carrier" as found in a broadcast program. Due to this lack of "carrier" all inter-character noise came through apparently untouched and the system was abandoned for use with code reception.

45. The second system proved unsuccessful and was abandoned. Although a balance could be obtained and complete cancellation effected of both signal and static, segregating the signal from the static was found to be impossible, probably due to the change in wave form on one side of the balance, which would not cancel the wave form on the opposite side when attempts were made to cause an out of balance condition to exist until the input amplitude reached a predetermined value.

46. The third system apparently operated somewhat as expected, but due to the rapid cut off of plate current when the decoupling grid was swung negative by the rectified current during inter-character intervals, the effect of this quick cut off or change in plate current would cause shock excitation of the following tuned circuits and the results showed but little change in the telephones, of the signal to noise ratio, and the idea was abandoned.

47. The fourth system calls for a change in the operating characteristics of the suppressor tube, and the bias was so adjusted as to cause plate current cut off when there is no signal. The system showed marked improvements over the former system (46) as the major part of the effect of the shock excitation during "no signal" intervals was eliminated. However, besides tuned circuits, there were critical values to be found by adjustment of the resistors R_1 and R_2 as well as an adjustment on the sensitivity control on the set, all of which could not be predetermined and had to be made after the signal had been picked up. This was seen to offer a serious drawback and the idea was abandoned. This system was also applied by an adapter which inserted the circuits of the unit into the output circuit of the last IRF stage.

48. The fifth system was that of creating A.F. harmonics from all signals and disturbances of greater than a predetermined amplitude and showed very gratifying results, the main drawback to this system being that the unit was inserted into the circuits of the set just ahead of the audio system, and did not protect the 2nd oscillator from being thrown out of oscillation or "paralyzed" when extremely heavy surges arrived, and a small portion of the signal such as a "dot" would be missed before the signal would be restored again in cases where the sensitivity control on the set would be advanced to increase the volume of a very weak station. However, on such stations as GBR (Rugby, England) where the "sensitivity" control did not have to be too far advanced, and under conditions where the static signal ratio was not unusually great, this blocking or paralyzing action was not noted. The adjustments of resistor values in the circuits of the unit could be made fixed and it became necessary to bring the gain of the receiver up only to the point where the peaks of the signal wave were reaching the critical amplitude of the unit, above which harmonics are created, so that the high amplitude static surges would go well above, and subsequently be lost in the audio selective filter in the set. Care had to be used not

to allow the signal amplitude to exceed by too great an extent this critical value, as otherwise the signal itself would reach well into the zone where harmonics are created and thus a large part of the signal itself would be apparently lost also. To relieve this critical adjustment, the benefit of a rapid amplitude control operating at radio frequencies and without apparent time lag, inserted ahead of the present harmonic generating stage, was apparent. After further consideration it appeared that if such an automatic volume control could be developed it would in itself accomplish the desired results. This led to the try-out of the automatic amplitude control in the following system.

49. This system of amplitude control is of such a nature that tuned circuits and variable resistors are not required for successful operation. The circuits of the tube are so arranged that above a predetermined amplitude, the output of the tube is such that there is no increase in output, this being caused by bringing about losses that are in direct proportion to the increase of the signal input above the critical value, never allowing the output of heavy static to be present at greater amplitudes than the desired signal. This was found to be quite effective and when the unit containing this system was inserted into the circuit in the last IRF stage, it was found that the paralyzing of the 2nd oscillator, such as was experienced with the system mentioned in (48) above, or when the unit was cut out of the circuit of the set, was eliminated, as was also the ringing effect in the selective audio filter, proving that the peaks of the static were levelled off approaching signal level in the radio frequency circuits without apparent time lag. After further consideration it appeared that in order to obtain the most satisfactory results it would be desirable to place the unit containing this system into the earlier circuits and thus avoid much of the shock excitation known to be existing in those stages upon the arrival of sudden heavy crashes, and accentuating the effect of the static in these earlier stages. The investigation of system #7 employing tubes now under construction will show the practicality of such an arrangement.

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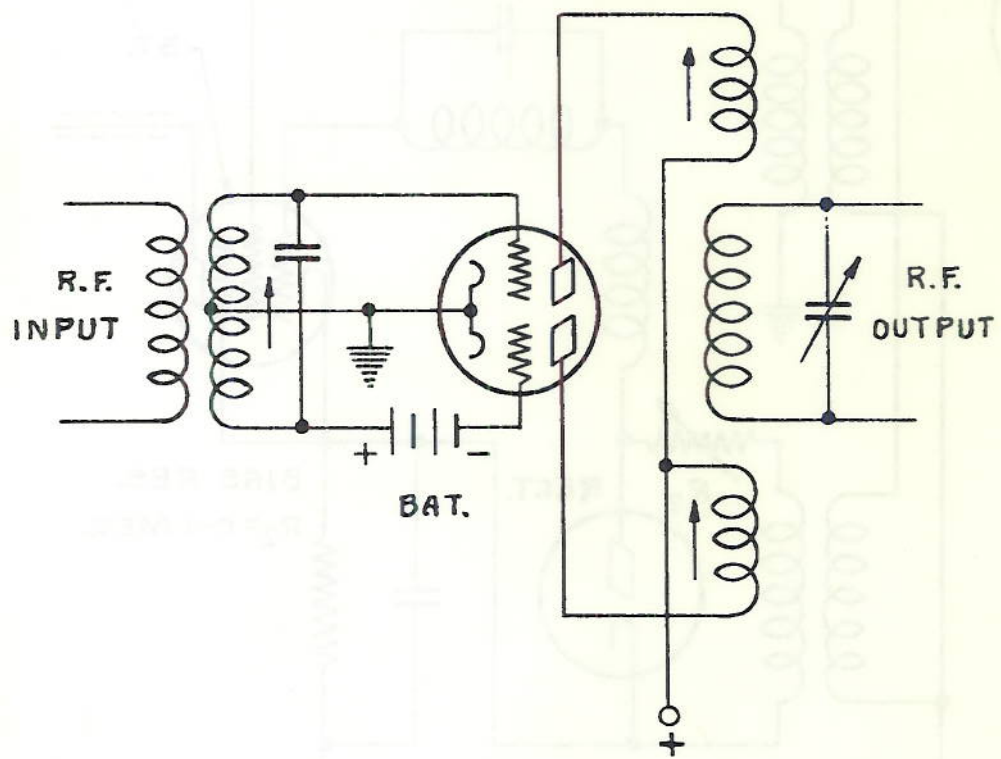


PLATE 2

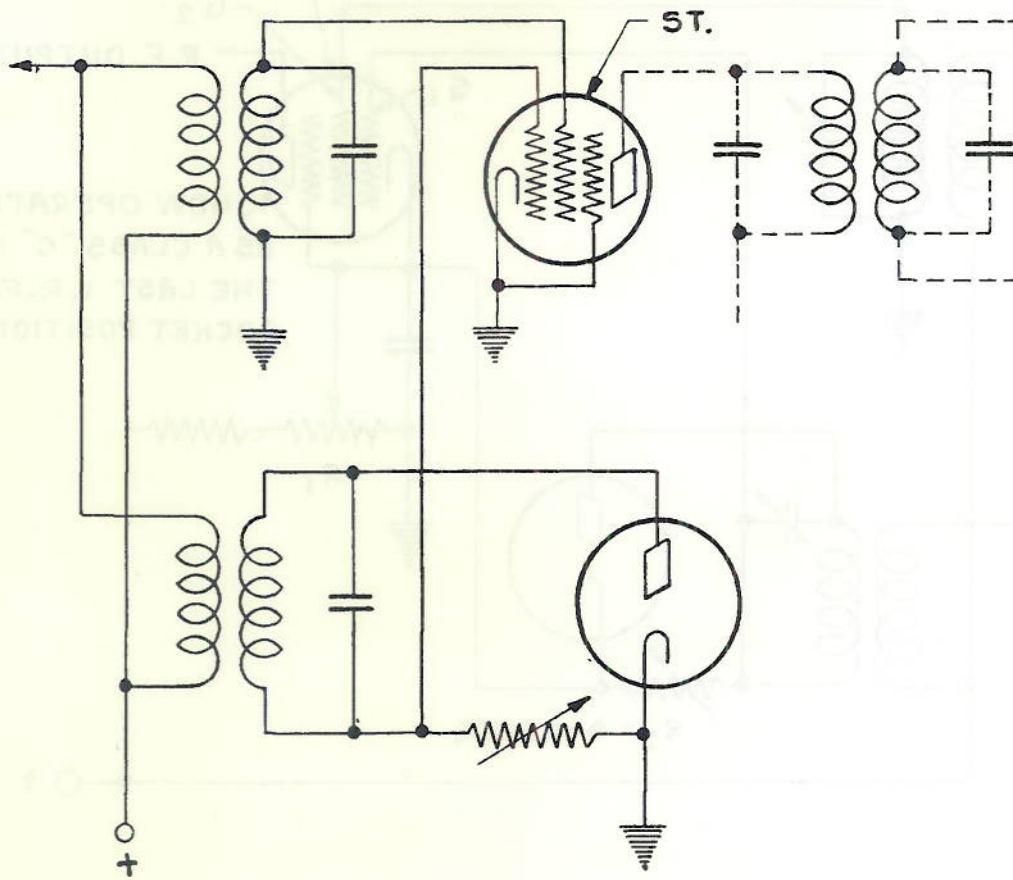
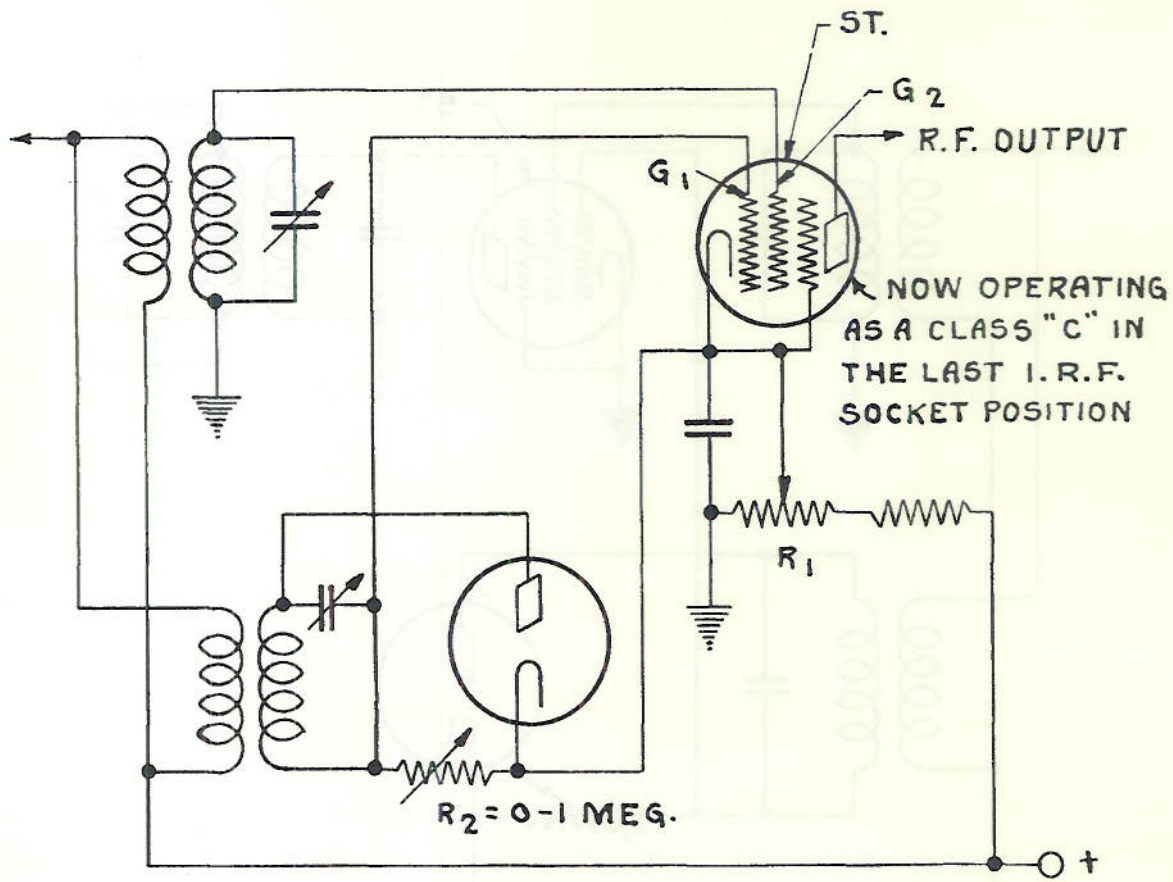
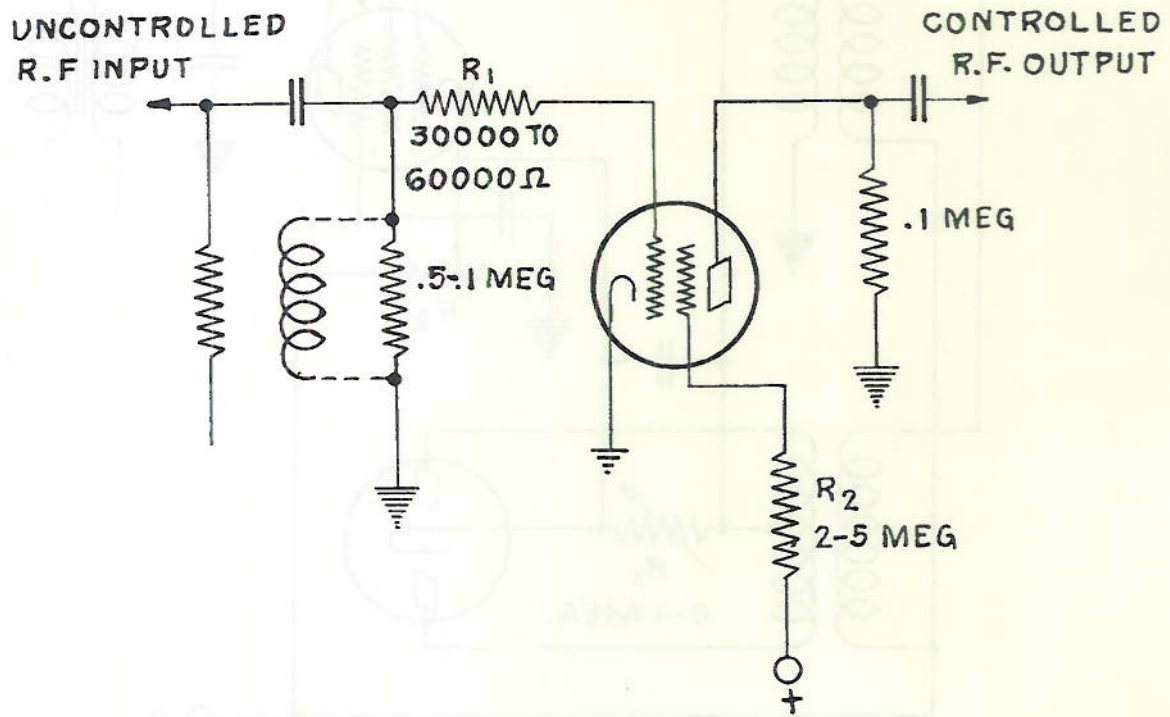
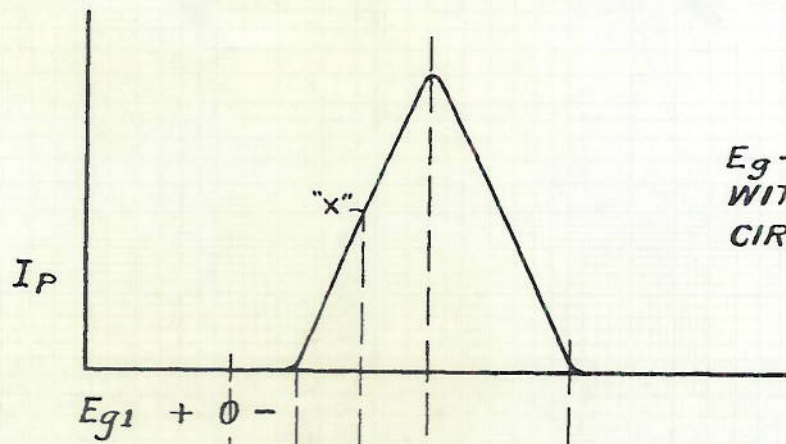


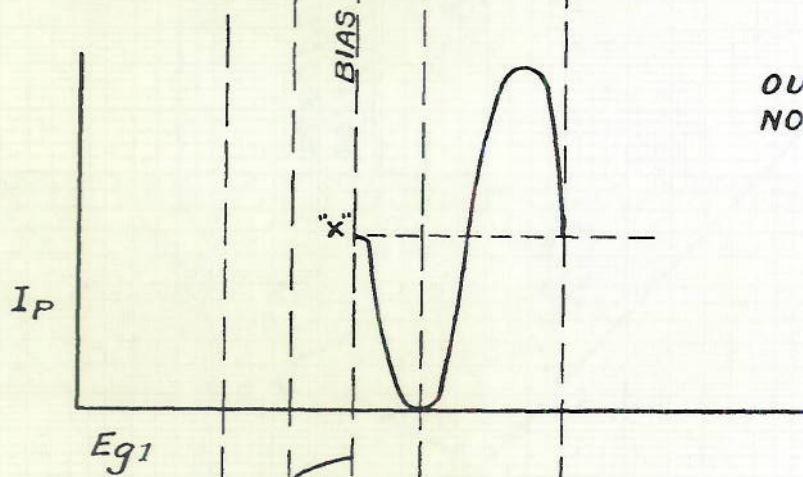
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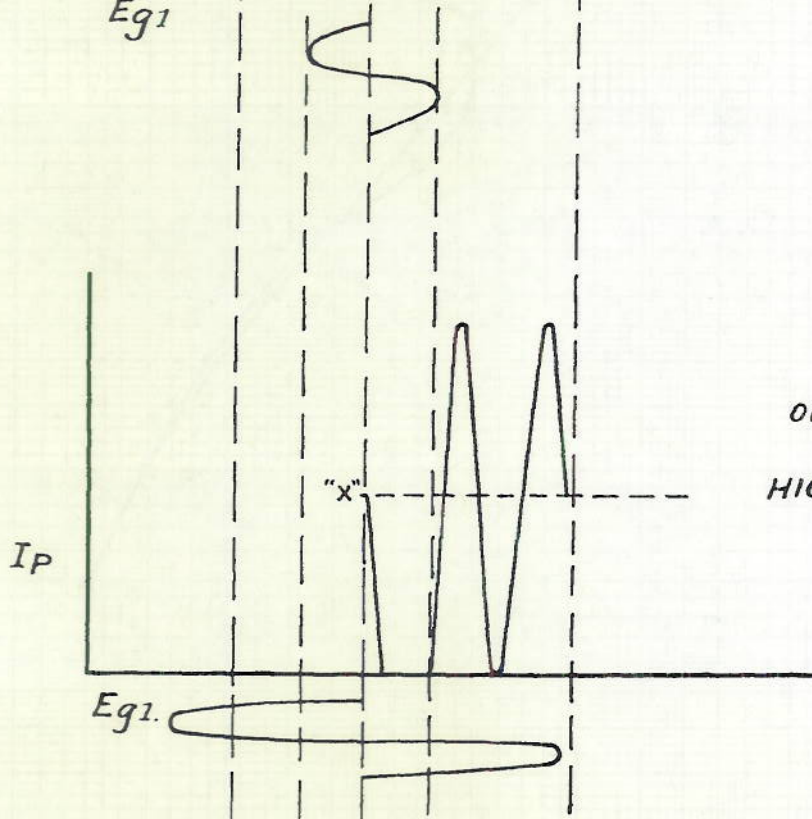




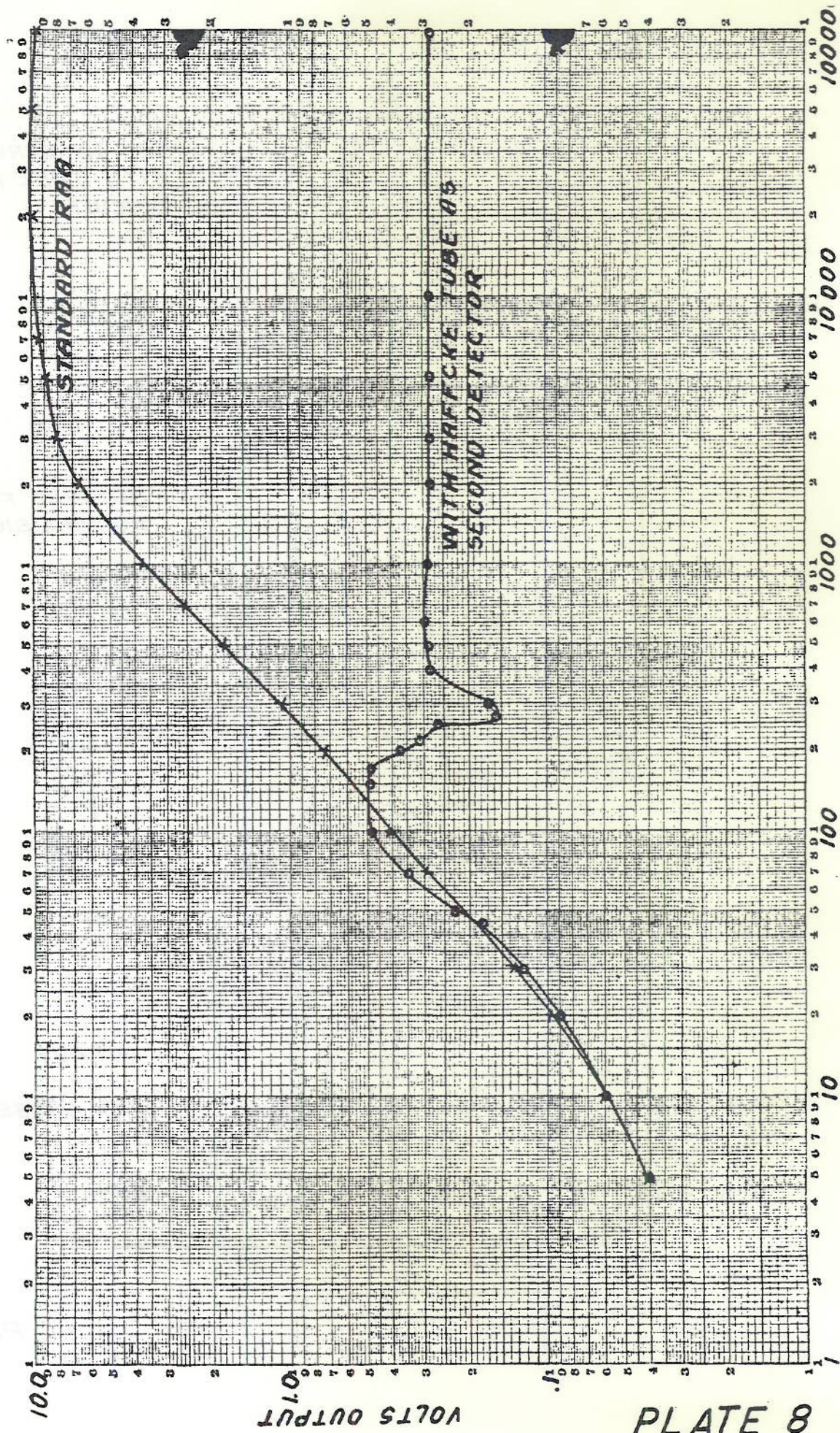
*$E_g - I_P$ CURVE,
WITH TUBE IN
CIRCUIT.*



*OUTPUT FROM
NORMAL SIGNAL.*



*OUTPUT
OF
HIGH SURGES.*



MICROVOLTS INPUT

VOLTS OUTPUT

PLATE 8