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# RADIOTRONICS

Volume 17 October 1952 No. 10

The Ashfield Factory of Amalgamated Wireless Valve Company Pty. Ltd.

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**Volume 17** **October 1952** **Number 10**

## *By the way—*

The rapid development of the U.S. television industry in the post-war years has surprised even those who predicted the brightest of futures for this new medium of mass entertainment. With millions of receivers now in use and millions more being demanded, television has become one of the fastest growing industries in America. Along with this great expansion, there has also grown a demand for trained technicians to service home television receivers.

Many Australian service and repair men, highly skilled in the techniques of radio maintenance, desire to familiarize themselves with the fundamentals of this new field, and so be prepared for the advent of Australian television operations.

To them, Radiotronics presents this television training course. Prepared by G-E engineers at Electronics Park, the course affords a clear, concise explanation of the basic principles essential to expert television maintenance.

It appears here through the courtesy of Australian General Electric and with acknowledgements to International General Electric of U.S.A.

A second edition of the Radiotron Valve Data Book, which was originally published in spiral bound form early in 1951, is expected to be on sale before the end of this year. This new edition will be completely revised and will contain data and curves on fifty per cent. more valve types than formerly. Further details of price and availability will appear later in Radiotronics.

The article dealing with a folded horn cabinet is reproduced with the permission of the Jensen Manufacturing Company.

The American Institute of Electrical Engineers have given us authority to reprint Mr. S. C. Bartlett's article. The information contained therein is equally applicable to a variety of industrial undertakings—steel mills, train announcing, automobile assembly works, etc.

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# P.A. SYSTEMS IN GENERATING PLANTS

**By S. C. Bartlett,**

The use of public address systems in generating plants is a special application of the device and has not been particularly well covered in the technical literature to date. It differs from other public address applications in several important respects and it is the intent of this paper to give the basic requirements and considerations leading to the design of a truly practical system. Trials in practical plants over the past 15 years provide a basis for selecting components most suitable.

The expression "public address" is a misnomer in this case in that the device is specifically not used for entertainment or group talks but is confined to many brief uses for paging, co-ordination of activities and emergency warnings. It would be better known as an "amplifier system" or "loudspeaker system".

## Other communication facilities.

First, it is necessary to consider what other devices for communication may be at the disposal of plant operators. Any or all of the following may be found:

1. Leased telephone lines. These circuits handle all normal business functions from the plant to the local central office and to long distance phones.
2. Intercommunicating telephones. These take care of person-to-person conversations within the plant and may or may not be tied through a PAX or PBX to external trunks.
3. Code calling. This is for paging key men throughout the plant and is usually a part of the intercommunicating telephone system.
4. Test telephone. This is a system of complete simplicity, being generally no more than a pair of conductors running throughout the plant with arrangements for plugging in handsets at any desired location.
5. Transmission telephones. These provide communications to substations for matters having to do with the flow of energy.
6. Carrier current telephones. These are provided for the long distance conversations to other plants and substations on the main transmission system and are used almost entirely for system operating functions.
7. Radio. Where provided, this is used primarily for dispatching line maintenance crews and sometimes serves for directing switching at remote, unattended substations.

## Need for public address systems.

With all of the foregoing facilities there is still need for some means of paging all plant personnel either individually or in groups, a means of conveying orders to groups of people simultaneously, a means of communication from any one of these individuals to the entire group, and a means of notifying all personnel in cases of emergency. This is capably disposed of by means of a properly designed public address (P.A.) system.

Modern plants with the multiplicity of devices provided to obtain high efficiency introduce problems of co-ordination of all personnel, the observations which they make, the readings of instruments and, in turn, the orders regarding control and adjustment. This is important during periods of start-up, synchronizing, load change, boiler blowdown and shut down of units and is especially necessary during emergencies or unexpected conditions requiring immediate changes to be made.

The present-day trend in plant design is in the direction of unit construction, in which case a separate P.A. system should be provided for each unit. These may be readily consolidated at one or more points for simultaneous control as in the case of fire or other emergencies involving the entire plant.

## History of development.

Early attempts to apply this equipment involved installations made by the manufacturer who, it often developed, was not fully cognizant of the problem, considering the noise levels involved, temperatures, humidity, and vibration. The equipment, therefore, was not properly adapted to the service and performance was poor. Such devices as crystal microphones with their inherent fragility would not today be considered for such an application. Similarly, microphones of low output level would not be considered except possibly by using a preamplifier at each microphone to reduce the susceptibility of the microphone circuit to pick-up from the many power conductors. Amplifiers attained a maximum rating of about 50 watts. Where additional power was required it was obtained only by using more 50-watt amplifiers. Thus if 250 watts output was required the tube complement of all amplifiers totalled something in the order of 50 to 60 tubes.

Another early error of judgment resulted from the attempt to cover entirely too much area with the result that reverberations from the building destroyed intelligibility at any appreciable distance from the loudspeakers. These early attempts, however, were not entirely wasted since they demonstrated that many useful purposes could be served by a properly designed system.

## Statement of the problem.

The problem, then, is to provide:

1. A system capable of paging simultaneously throughout the entire plant.
2. A system providing speech coverage in all operating areas.
3. A means of reply or break-in from any operating position.
4. A simple means for adjusting audio power level for any background noise level from that of office areas to that of fan floors.

## Basic considerations.

Knowledge of noise levels and reverberation characteristics coupled with an understanding of the manner in which a plant is operated leads to the premise that it is unnecessary and, in fact, improper to attempt to cover all plant areas except possibly for paging. The essential requirement is met by selecting and locating speakers to cover only observation and control areas where personnel are normally stationed. The speakers may then be supplemented by a means of conveying detailed information without error. High reliability must be achieved through selecting components designed to withstand extremes of temperature, humidity, dirt, and mechanical abuse. Consideration must be given to the great lengths of microphone and speaker cable, their selection and installation as a matter of minimizing susceptibility to magnetic and electric fields. The method of operation at each control point must be as simple as possible. The circuits employed must be held to basic simplicity to avoid becoming future sources of trouble and so maintenance work may be done without the necessity of calling in people with special skills or equipment.

## Reverberation characteristics.

Assuming that it is impractical to provide acoustic treatment of any areas other than offices or control room, it is necessary to adapt speakers to the plant as it stands. If, for instance, it were attempted to cover an entire turbine room floor from a single speaker, it would be found impossible regardless of the sound power employed because the large ceiling, wall and floor areas cause reverberation sufficient to completely destroy intelligibility. Illustrative of this was an early attempt to use an extremely high power horn speaker at one end of a turbine room floor. This device operated on the principle of modulating a flow of air from a compressor and produced sound volumes comparable to 500 watts of audio power with good intelligibility. With this device located at one end of the turbine room floor, high sound levels were produced throughout the entire 60 by 225 foot area. However, beyond about 60 feet from the source, words were completely unintelligible and the only thing heard was substantially a monotone determined by the reverberation characteristics of the room itself. If the entire area must be covered, the solution here is through the use of many small units. Actually we find that a practical solution results from the use of a single speaker at the turbine control panel or at the control end of each unit to concentrate all sound energy in those areas where operators are normally on duty. Similar logic applies to the application on the fan floor or other places where large wall areas may reasonably be expected to give trouble. Throughout the remainder of the plant the space is very largely broken up by pipes, tanks, columns, and machinery, such that reverberation is not a problem.

## Noise levels.

Many observations were made in both old and new plants using Western Electric Company sound level meter type 700-A. These readings are tabulated in Table 1, the values being in decibels above the threshold of hearing, which is taken as zero level, or $10^{-16}$ watts per square centimetre. Noise levels indicated are generally between 80 and 120 decibels with a few exceptions as in sound-proofed offices and control rooms.

## Audio power requirement.

Table 1 gives average noise levels based on observations in practical plants. The final column indicating loudspeaker watts for each location has been determined by experience. This is not directly related to the noise level since there is an additional factor of the area to be covered. Note that the average for an entire plant is in the order of 10 watts per speaker and the total requirement for a single unit plant is in the order of 250 watts.

**Table I. Noise Levels and Speaker Power Requirements.**

| Location | Decibel Level | Speaker Power Watts | |
|---|---|---|---|
| | | A | B |
| 1. Fan floor | 95-120 | 20 | 20 |
| 2. Fan floor | 95-120 | 20 | |
| 3. Coal conveyor | 92- 97 | 20 | |
| 4. Coal pulverizers | 96-103 | 10 | |
| 5. Scale floor | 95-105 | 10 | |
| 6. Heater floor | 92- 97 | 20 | |
| 7. Burner deck | 93-101 | 10 | 10 |
| 8. Burner deck | 93-101 | 10 | 10 |
| 9. Utiliscope (water level) | 95 | 5 | |
| 10. Utiliscope (burners) | 95 | 5 | |
| 11. Evaporator floor | 93- 95 | 10 | 10 |
| 12. Control room | 70- 91 | 5 | 5 |
| 13. Turbine room | 93-107 | 20 | 20 |
| 14. Turbine control panel | 90-105 | 10 | 10 |
| 15. Steam driven exciter | 100-103 | 10 | |
| 16. Boiler control panel | 93-103 | 10 | 10 |
| 17. Boiler room basement | 100 | 20 | 20 |
| 18. Boiler room basement | 100 | 20 | 20 |
| 19. Turbine room basement | 90-107 | 20 | 20 |
| 20. Feedwater pump | 102-105 | 20 | 20 |
| 21. Condenser pit | 95-103 | 20 | 20 |
| 22. Circulating pump | 91-104 | 10 | 10 |
| 23. Pump panel | 98-105 | 10 | 10 |
| 24. Condensate panel | 102 | 10 | |
| 25. Hotwell pumps | 99 | 10 | |
| 26. Machine shop | 75- 85 | 10 | 10 |
| 27. Elevator | 81- 96 | * | * |
| 28. Superintendent's office | 67- 75 | 0.5 | 0.5 |
| 29. Watch engineer's office | 74- 81 | 0.5 | 0.5 |
| 30. Electrician's office | 74- 81 | 0.5 | 0.5 |
| 31. Storeroom | 83 | 5 | 5 |
| 32. Amplifier room | 75- 85 | 0.5 | 0.5 |
| 33. Electric gallery | 84- 91 | 5 | |
| 34. Chem. laboratory | 78 | 1 | |
| 35. Results department | 82 | 1 | |
| 36. Lobby | 82 | 5 | |
| 37. Hallway | 77- 91 | 1 | |
| 38. Screen House | 93 | 10 | 10 |
| 39. Transformer yard | 91- 96 | 10 | |
| 40. Outside, near plant | 75- 95 | 10 | |
| 41. Outdoor substation | 71- 82 | 10 | |
| 42. Gate house | 73 | 1 | |
| Total power | | 406 | 242 |
| Number of speakers | | 41 | 22 |
| Average power | | 9.9 | 11.0 |

Column A — Complete coverage.
Column B — Minimum requirements.
* Handset but no speaker provided.

## Loudspeakers.

In the production plant itself and out-door areas, all speakers should be of the horn-type, using either straight trumpets or re-entrant horns. For our purposes, the smallest horns manufactured are entirely suitable. Specifically, a horn providing $2\frac{1}{2}$ to $3\frac{1}{2}$ foot air column with a bell diameter of 12 inches will pass everything from 250 to 5,000 cycles essentially without distortion.* Inasmuch as the intent is to cover only selected areas, these horns should be chosen with not more than 40 degrees spread at 1,000 cycles. Drivers of the permanent-magnet type attained a high degree of development for military applications and are available today in forms which are largely impervious to temperature, humidity, vibration or dirt, as would be encountered in a generating plant. These are available in various sizes from 5 to 25 watts. For simplicity and interchangeability, it is recommended that just one type, say the 25-watt size, be provided.

In the control room a ceiling type 360-degree unit may be employed although, since only a low power is required, a small 5 inch cone speaker mounted in one control panel is adequate. For office areas the sloping panel type speaker mounted at the junction of wall and ceiling is quite satisfactory. In large offices where only certain of the employees are directly concerned with operation of the physical plant, it is convenient to use one or more small desk speakers in plastic housings such as are commonly employed for interoffice communicating systems.

**Microphones.**

Having in mind the overall response characteristic indicated in Figure 1 and discussed in the paragraph under Amplifier Characteristics, it is apparent that any modern microphone will provide adequate fidelity. Crystal microphones should be definitely avoided because of their fragility and the fact that they are subject to damage from temperature and humidity. Dynamic microphones would be quite suitable but in general involve more expense than necessary. The real practical solution appears to be through the use of a conventional carbon microphone handset. These have been highly developed, specifically for transmission of speech intelligibility and are most desirable in this application because of their extreme ruggedness, low cost and general availability. There is one further advantage in that they provide a high-level low-impedance source which very materially reduces the susceptibility to pick-up in the long microphone line which may run to the order of 1,000 feet. Also, no preamplifiers are required either at the individual microphones or ahead of the main amplifying device. Since the system involves only a total amplification in the order of 60 decibels, the matter of microphone hiss is not a problem.

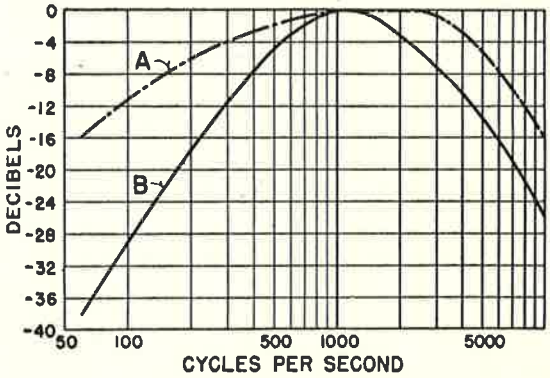
In levels of extremely high noise, intelligibility of sound coming from loudspeakers is limited to simple words, names or phrases. For anything more detailed, it is necessary to listen to a telephone receiver and, where the room noises are particularly bad, to have the additional protection of a soundproof booth. The conventional monophone suggested above serves very well for this additional function.

**Microphone supply.**

Considering the necessity of controlling plate voltage and the need to cut off local loudspeakers, the simplest means is through the use of microphone current for control. Thus the microphone supply must not only be adequately filtered but should have high enough voltage to operate two relays in series with the microphone. Assuming that 600-ohm telephone relays and a conventional carbon microphone are used, this requires a 48-volt supply which is available in any of a number of forms, for instance, as a power supply for use in small telephone exchanges or as a part of a carrier current telephone set or a radio transmitter. This arrangement also has the advantage that no additional conductors are required for control.

**Amplifier characteristics.**

The first thought is normally for a means of designing or selection of high fidelity equipment. However, we must realize that in this application there is no intent to use the device for entertainment or reproduction of music. Not only is capability along these lines unnecessary, but for our purposes would be actually detrimental. In a power plant the background noise, although high, does tend to concentrate at either end of the audio spectrum. Thus we have many rumble noises as from crushers, fans and hum from motors and transformers. At the upper end of the spectrum we have the characteristic screaming of turbine blades and feedwater pumps.



What would be called a high quality amplifier for voice might have an overall fidelity characteristic as indicated by curve A of Figure 1, which is flat from 1,000 cycles to 2,500 cycles and down 6 decibels at 200 cycles and 5,000 cycles. Even this is far more linear than required and an amplifier with characteristics as indicated in curve B would be quite satisfactory. This peaks at about 1,000 cycles and is down 6 decibels at 500 cycles and 2,500 cycles. In a power plant there is much opportunity for magnetic pick-up into the microphone circuits of 60-, 120-, and 180-cycle frequencies and here, again, the amplifier response to these low frequencies must be held down. Thus, continuing curve B, the roll off below 500 cycles and above 2,500 cycles could be designed for about 12 decibels per octave. This, and in fact the entire shape of the overall characteristic, may be obtained by very simple resistance-capacity networks.

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*** Refer Radiotronics, March, 1952.**

Figure 2 indicates the effect on syllable articulation of removing portions of the speech frequency range.[4] Note that no substantial improvement results from extending this range either below 400 cycles or above 3,000 cycles and adequate intelligibility will be attained by concentrating all audio energy within this range.

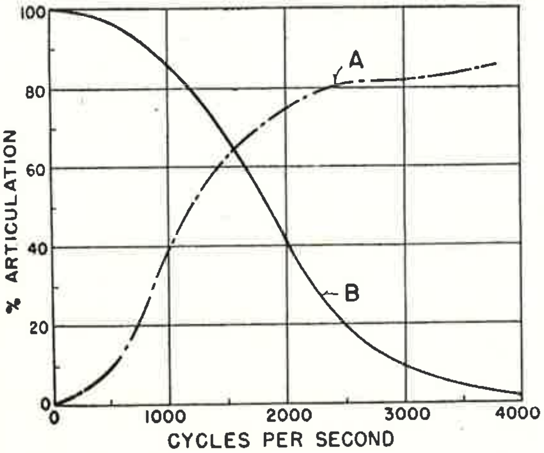

*Fig. 2. Effect on syllable articulation of removing portions of the speech frequency range.*[4]
*All frequencies, A below, B above, the indicated frequencies transmitted.*

Consider further Figure 3 which indicates the relation between articulation and energy distribution of speech. Note that about one-half of the total energy is confined to the frequencies below 500 cycles but these frequencies contribute only 5 per cent. to the intelligibility. By eliminating most of these and concentrating everything in the 400- to 3,000-cycle range, a given size of amplifier and number of speakers will provide far better performance.

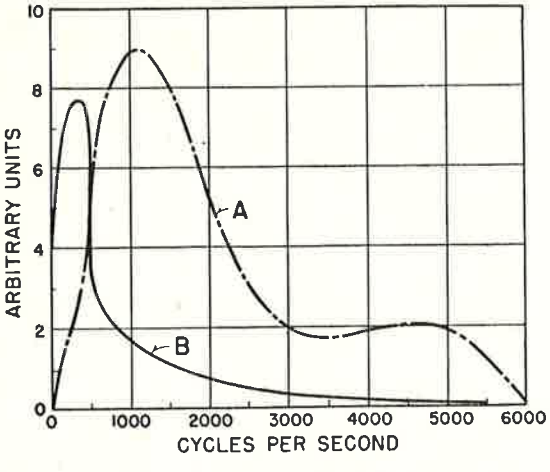

*Fig. 3. Relation between articulation and energy distribution of speech.*
*A—Relative importance for intelligibility.*
*B—Energy distribution.*

## Design of amplifiers.

For this type of work where the equipment will operate continuously under conditions of temperature variations, humidity and vibration, carefully planned mechanical design, along with simplicity of electrical components, is essential. By proper design the number of tubes should be minimized and any critical circuits should be carefully avoided. High impedance circuits, characteristic of resistance coupled amplifiers and phase inverters, should be avoided by using transformer coupling throughout.

A simple and practical arrangement would be through the use of a single triode, say type 6C4, or a pair in push-pull for the input stage followed by a pair of 807's triode-connected, in push-pull as a driver stage, these all being operated in class A, and followed by a final stage consisting of a pair of 805's in push-pull operating as either class AB or class B. A pair of 866A tubes would suffice as plate supply for the final stage using a bleeder to feed input and driver stages. If desired, the input and driver stages could be supplied from a low-voltage rectifier which might include microphone supply mentioned before. Thus the entire amplifier, including rectifiers, totals only seven or eight tubes.

The audio range should be limited at the input to conform to either curve "A" or "B" indicated in Figure 1. As mentioned previously, total output power requirements will be in the order of 250 watts. If we assume an input power in the order of 25 milliwatts, the entire gain comes out to be 60 decibels. Both microphone and speaker lines could conveniently be designed for 60 ohms.

Degenerative feedback for final stages using beam power tubes is conventional and can be introduced with little difficulty to reduce distortion, noise and instability caused by voltage fluctuation and, at the same time, improve output regulation of amplifier.

Assuming class AB or B is used in the final stage, a power supply of good regulation is required. This is readily accomplished through the use of mercury rectifier tubes with choke input filter. Considering the comparatively low gain of the amplifier, there will be no trouble from rectifier tube noise if a conventional hash filter is employed.

The transformers themselves must be designed with due consideration for such factors as saturation of core material, symmetry of windings, avoidance of resonance, low loss, adequate shielding against hum pick-up from chokes and other transformers. Many well designed transformers are available.

## Choice of tubes.

The basis for choice of tetrodes or triodes may be argued. However, either may be employed to produce an amplifier of adequate fidelity. Our own choice for audio work of this nature is the triode since there is some reason to believe it is more capable of retaining its original characteristics throughout its life and is somewhat less subject to failure from "hot shorts". Considering the comparatively low total gain, separate cathodes are not required except possibly in the first stage. Conventional receiving type tubes are available in many types for the input and driver stages and many transmitter tubes, such as types 211, 805, 810, 811-A, 813, 838, 845, can be used in the final stage.

### Plate voltage control.

Since amplifying systems of this type are in use for only a very few per cent. of the total time, it is advisable to disconnect the plate supply during the idle periods. This is a very simple matter and will result in material extension of tube life and, at the same time, will reduce temperatures of all other components of the amplifiers, thus similarly extending their lives. A thermal relay should be incorporated in the plate supply as a matter of protecting the rectifier tubes whenever the supply voltage may be interrupted and restored.

### Amplifier mounting.

For convenience and simplicity, all equipment should be mounted in a cabinet with: the 48-volt relay-microphone supply; a panel containing speaker and monophone for local operation; a control chassis carrying equipment for plate supply control; the main amplifier; and terminal boards for the microphone, speaker, and power connections. In plants where a separate room is available for communication equipment, a relay rack will provide excellent mounting.

### Location of amplifier.

In a power plant there are many possible locations. If a separate room is provided for the telephone switchboard, carrier current equipment or other electronic devices, it would be ideal. Otherwise, there may be space in the control room or one of the offices. If none of these is practical, an amplifier designed along the lines indicated above can be located almost anywhere as long as the ambient temperature does not exceed about 90 degrees Fahrenheit and the equipment will not be subjected to excessive vibration or direct spatter of liquids.

### Handset volume level.

The standard desk set cords and handset cords are not available as shielded conductors or even with the microphone lead shielded. It is therefore important to reduce the level of the speaker line to handset level before bringing it into proximity to the microphone lead. Thus the speaker line in the control box goes immediately to the relay and then through resistances to the flexible cord. The value of these resistors may be changed to produce any desired receiver volume depending on the background noise level. Using resistors in pairs to maintain balance and assuming a 122.5-volt speaker line (250-watt amplifier, 60-ohm line) and handset receivers of 60 ohms each, the receiver power levels shown in Table II will be produced.

### Table II.

| Ohms | Total Watts | Watts in Receiver |
|---|---|---|
| 2,200 | 3.36 | 0.0452 |
| 3,300 | 2.25 | 0.0203 |
| 4,700 | 1.58 | 0.0100 |
| 6,800 | 1.10 | 0.00483 |
| 10,000 | 0.749 | 0.00224 |
| 22,000 | 0.340 | 0.000463 |
| 33,000 | 0.227 | 0.000206 |
| 47,000 | 0.160 | 0.000102 |
| 68,000 | 0.110 | 0.0000485 |
| 100,000 | 0.075 | 0.0000225 |

### Handset mountings.

The conventional wall mounting hook-switch is suitable for all locations except in telephone booths and in offices where the desk set is preferred. No dial, ringer, capacitor, or induction coil is required. One make contact of the hook switch is used to control microphone current.

### Speaker transformers.

These matching transformers serve the purpose of matching the impedance of all speakers in parallel to whatever impedance it is desired to operate the speaker line. Thus the individual speakers are set for impedances considerably above that of the line itself. For instance, if a line is operated at 60 ohms, the impedance to be used to obtain any desired speaker power is given in Table III.

### Table III.

| Speaker Power, Watts | Transformer Z, Ohms |
|---|---|
| 25 | 600 |
| 20 | 750 |
| 15 | 1,000 |
| 10 | 1,500 |
| 5 | 3,000 |
| 2.5 | 6,000 |
| 1 | 15,000 |
| 0.5 | 30,000 |

For simplicity it is suggested that all horn speakers be equipped with 25-watt adjustable transformers to cover the impedance range from 600 to 3,000 ohms. Transformers for all other speakers could be 5 watts rating with input impedances from 3,000 to 30,000 ohms.

For example, if we took the installation suggested in Table I under condition B, there are seven 20-watt speakers, nine 10-watt speakers, two 5-watt speakers, and four $\frac{1}{2}$-watt speakers. Using transformer input impedances as indicated above, we get the following figures:

7 units, each 750 ohms in parallel = 107 ohms
9 units, each 1,500 ohms in parallel = 167 ohms
2 units, each 3,000 ohms in parallel = 1,500 ohms
4 units, each 30,000 ohms in parallel = 7,500 ohms

Total $Z$ =

$$\frac{1}{1/107 + 1/167 + 1/1{,}500 + 1/7{,}500} = 62$$

$$\text{Total power} = \frac{(122.5)^2}{62} = 242 \text{ watts}$$

### Cables.

For both microphone and speaker lines there are many practical choices. We would suggest that these be restricted to the types generally to be found in plant stocks for which fittings are immediately available and with which the plant personnel are thoroughly familiar. For instance, the speaker line could consist of either BX or number 12 AWG weatherproof wire in conduits. For the microphone line type BXL would be excellent. The characteristic impedance of these lines is not a factor since for the highest frequency handled, say 3,000 cycles, we have a wavelength of approximately 62 miles compared with a length of the longest run of cable in the order of 1,000 feet.

It is advisable, wherever possible, to keep microphone and speaker leads in separate conduits. The microphone circuit may be carried in the same conduits with other signalling circuits if desired.

### Control room switchboard.

In addition to the loudspeaker and the desk set the control room should have jacks in the panels such that an operator may use a portable monophone while working at the panels, reading instruments, and making adjustments. A conventional double telephone jack located every alternate panel will be adequate. The operator uses a standard monophone with 4-wire cord and double plug. Plugging in the portable monophone accomplishes the same thing as picking up the desk set monophone in that the local speaker is cut off.

### Control boxes.

To eliminate acoustic feedback it is necessary to provide a relay at each control point to cut off the local speaker when its associated monophone is off the hook. For convenience, this is mounted in a 12 inch by 12 inch by 4 inch steel box, Figure 4, with a 10-microfarad capacitor by-passing the relay coil, a pair of fixed resistors to apply a low level signal to the handset receiver, and an adjustable speaker transformer. The steel box is well adapted to welding or bolting to steel structures throughout the plant and is of ample size to accommodate BX, BXL or conduit. For office areas, the same components in smaller size may all be built into a standard telephone ringer box.

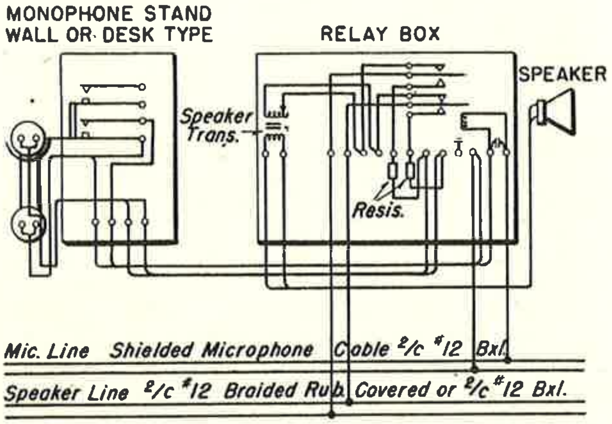

*Fig. 4. Circuit for relay control box, handset, and hook-switch.*

### Overall performance.

As it normally functions, the system is put into operation by lifting any monophone which, in turn, applies plate voltage and the call is received by all speakers. Assuming that a certain person is called, when he picks up the monophone at some other point, a high quality telephone channel is established with receivers at each end adjusted in amplitude depending upon local noise levels. It would then be a simple matter to cut off all loudspeakers. However, experience indicates that it is better to leave them in operation. Thus, all personnel are fully informed of any contemplated changes being discussed and may prepare to make such adjustments as necessary on the equipment under their control.

In general, the sound power being concentrated in that part of the frequency range conveying maximum intelligibility, the overall performance is very good. However, it must be recognized that in the extremely high noise level areas, the best that can be expected from loudspeakers is ability to understand simple words or phrases. "It is common experience that when any sound is impressed upon the ear, it reduces the ability of the ear to sense other sounds."[4] Each tone tends to mask those near and above it in frequency. As would be expected, masking by complex sounds is the composite masking of each individual tone. In these areas the P.A. system serves for paging only, after which the transmission of intelligence is accomplished by the local monophone with the protection of a soundproof booth.

The cost is an extremely variable factor but in no case should exceed 1/20th of 1 per cent. of the plant value and is readily recovered by improved personnel efficiency, plant performance, and reduction of damage during emergencies.

### Maintenance.

Equipment as indicated above requires very little maintenance. The circuits are simple and straightforward and very few tubes are used. There is very little reason for duplicate equipment, and maintenance can be handled by anyone with average understanding of audio circuits equipped with basic tools and a volt-ohmmeter. A tube tester is hardly essential since conventional types will handle only the receiver tubes used on the input and driver stages. For most work, all that needs to be done is to check tubes by interchanging with new tubes, observing the resultant values of tube voltages and currents. The power output level may be checked approximately by observing the voltage across the speaker circuit, using voice or whistle as an input to the microphone circuit. If it is desired to be more precise, an audio oscillator should be provided. With this instrument, it will be possible at any time to restore the full original characteristics of the amplifier through the ability to observe the actual gain at any frequency. Speakers are seldom a source of trouble. Handsets are subject to some damage and it is reasonable to expect to replace handset cords from time to time. It would be advisable to stock spare tubes, filter condensers, handsets and handset cords.

### Conclusions.

It is felt that by adhering rigidly to practical considerations as detailed herein a device may be produced using commercially available components in circuits of basic simplicity, attaining high performance characteristics at low cost to provide a service not possible by other communication devices either separately or in combination.

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3. **MANUAL OF SOUND SYSTEMS, L. B. COOKE. Bell Telephone Laboratories (New York, N.Y.), 1939.**
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# BRIEF ANALYSIS OF THE TELEVISION SYSTEM

## 1. Introduction.

Before attempting to cover the various circuits, installation and adjustments of television receivers, it might be well to first consider a few facts concerning the make-up of a television system.*

Television as we know it today is an outstanding tribute to man's insatiable desire for new and better things. It deals with the systematic sub-dividing and conversion of a picture or scene into corresponding electrical impulses, whence it is conveyed to a receiver and assembled in proper order and position to form a complete picture again. It also deals with the means for obtaining proper synchronization between the transmitter and receiver for the correct synthesis of the picture elements and the simultaneous transmission and reception of the sound accompanying the picture.

## 2. General consideration.

Needless to say, the television system is considerably more complex than the more familiar sound broadcasting system. The basic elements of a typical television system are shown as a block diagram in Figure 1-1, in order to better visualize the operation of the system as a whole.

As shown, two separate transmitters are employed, one for the sound channel and the other for the picture channel. The sound transmitter is frequency-modulated and simultaneously transmits the sound which accompanies the picture. Each transmitter has its own antenna.

With the television transmitter, a pick-up device known as an ICONOSCOPE or TELEVISION CAMERA is used in place of the microphone at the sound transmitter. The image being televised is picked up by the television camera which converts the optical image or scene into electrical impulses. These electrical impulses corresponding to the scene are amplified by the video or picture amplifier. After suitable amplification, the video signal modulates the high frequency carrier of the television transmitter and is radiated into space by the antenna. The picture carrier is amplitude-modulated.

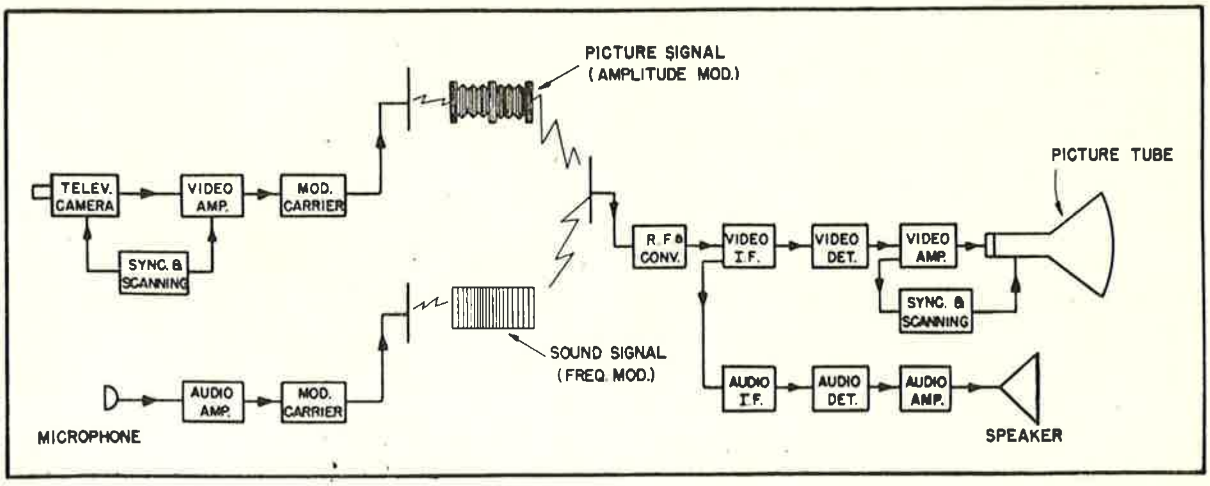
In addition to the picture impulses, special signals are sent out by the television transmitter for the purpose of synchronizing the picture at the receiver with that being picked up by the camera. The details of the scanning and synchronizing arrangements used will be considered in subsequent chapters.

At the television receiver, the picture and audio signals are picked up simultaneously by a single antenna. The voltages induced in the receiving antenna are fed into the r-f stage of the receiver, and the picture carrier and the sound carrier are converted by the superheterodyne conversion method into two separate intermediate frequency signals, one corresponding to the sound carrier and the other to the video or picture carrier with its associated side-bands. Two separate i-f amplifier channels are employed, one for the picture signal and the other for the sound signal, the details of which will be considered when the actual circuits are discussed.

The sound i-f signal after suitable amplification is demodulated by an FM detector. After sufficient amplification by the audio amplifier, the sound signal is reproduced by the loudspeaker in the usual way.

The picture i-f signal is amplified by several stages having wide-band frequency characteristics and is then fed into the video (picture) detector, where the i-f signal is then demodulated in the same fundamental manner as in an ordinary sound receiver. The video (picture) signal which appears in the output of the detector is then amplified in a video amplifier, which corresponds to the audio amplifier in a sound

*Fig. 1-1. Television system.*



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*** The U.S.A. system is the one referred to throughout this course.**

receiver except that it must pass a much wider range of frequencies for reasons to be discussed later.

In place of the loudspeaker used in the sound system, a device is used which converts the varying amplitude of the video signals into corresponding variations of light which reproduce the original scene.

The picture reproducing device is a cathode ray tube, similar in many respects to the ordinary cathode ray tube used in service shop oscilloscopes. The cathode ray tube may be called a picture tube because of the fact that the desired picture is reproduced on the face of this tube. Without going into the details of the cathode ray tube at this time, we will assume that it consists of a glass envelope, a source of electrons which are formed into a beam, a control grid for varying the intensity of the electron beam, a deflection system for deflecting the beam, and a screen coated with a fluorescent material that emits light upon impact by the electron beam.

The fundamental action of the C-R tube in reproducing a picture consists in the electron beam moving horizontally and vertically simultaneously so as to cover the entire area of the picture tube screen at the same time that the intensity of the spot is being varied by the video signal which is applied between the grid and cathode elements of the C-R tube. The control grid of the picture tube controls the intensity of the beam which strikes the screen in exactly the same way that the control grid of an amplifier tube controls the plate current. In this way, each portion of the picture tube is made to have the proper degree of light or shade to reproduce the original scene.

The brief description of the action taking place in the television receiver omitted the necessary scanning and synchronizing action which locks or synchronizes the picture at the receiver with that at the television camera. However, in the receiver, the synchronizing and scanning action takes place between the output of the video amplifier and the picture tube as shown by the block marked SYNCHRONIZING and SCANNING in Figure 1-1. The details of this action will be considered later after we have considered the exact need for scanning and synchronization.

### 3. Basic structure of a picture.

Before considering the process of converting the image into an electrical signal, it is necessary to consider the elements that make up a picture.

The basic structure of any picture consists of small areas of light or shade, known as PICTURE ELEMENTS.

The amount of detail in the picture depends on the size and number of elements making up the picture. For fine detail, the picture elements should be small and numerous as in an ordinary photograph and are not visible except on very close inspection. However, if the picture elements are few and large, they will show quite plainly as evidenced by the half-tone engravings employed in newspapers.

The number and size of picture elements required for satisfactory visual representation depends upon two factors: the amount of detail desired, and the distance at which the picture is to be viewed.

It has been found that if a television picture has approximately 200,000 picture elements it will have adequate detail. However, the distance at which it should be viewed for a pleasing picture depends upon the size of the screen. If a picture containing approximately 200,000 elements is enlarged to say twice its size, then the picture elements will be larger, and, if viewed close to the screen, it will not appear as pleasing as it would if viewed from a greater distance where the individual picture elements seem to blend into one complete picture. It is for this reason that the picture on a large screen appears much better at some distance from the screen.

### 4. Electrical transmission of an image.

As mentioned previously, the optical image is changed into a corresponding electrical signal which is then transmitted to the television receiver. However, the picture elements contained in a picture are not transmitted simultaneously since this would involve thousands of separate channels. Instead, the optical image is changed into an electro-sensitive image which is then dissected into its individual picture elements or electrical impulses by a process known as SCANNING, and only one picture element is transmitted at any one instant.

The process of scanning is similar to the manner in which a reader scans a printed page reading from left to right, dropping down toward the bottom of the page after each line of type has been scanned or read from left to right. In this way the electro-sensitive image produced by the action of the television camera is scanned line by line until the entire image has been dissected into thousands of separate electrical impulses which represent the individual picture elements of the scene being televised. In the present television system the image is scanned into 525 lines, which gives a picture detail of approximately 200,000 picture elements. One complete picture of 525 lines is referred to as a FRAME.

### 5. Successive method of transmission.

The method by which the individual electrical impulses contained in each scanned line of the image are transmitted is known as the SUCCESSIVE METHOD OF TRANSMISSION.

With this method only one communication channel is employed and the picture element impulses are sent one after the other in orderly sequence at a very

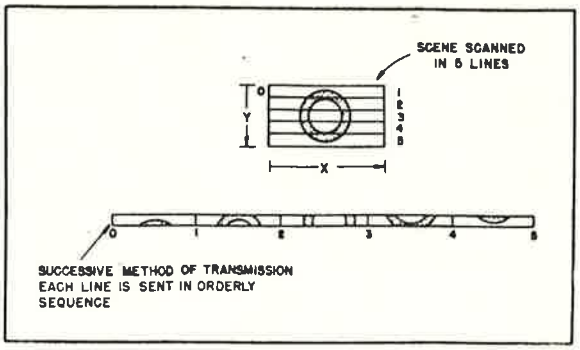


*Fig. 1-2. Principle of scanning.*

rapid rate. This can be illustrated by drawing a simple scene, such as in Figure 1-2, and scanning it in — say — five lines as shown. It should be noted that the scanning is a smooth, continuous process and that the scene is transmitted by being divided into horizontal lines containing picture elements, each of which is sent as a varying current wave.

The same scanning process is employed at the picture tube of the receiver where the electrical impulses are changed back into light impulses in the same orderly sequence in which they were transmitted, thus reproducing the original scene on the screen of the picture tube. Actually, the scanning process at the receiver is synchronized with that at the television camera so that at any instant the picture tube will simultaneously reproduce the same line that is being scanned at the camera.

### 6. Persistence of vision.

The effectiveness of this method of transmission is dependent upon the persistence of vision, and this scanning process must be quite rapid if the eye is to receive the illusion of a complete picture.

Persistence of vision is the ability of the eye to retain an image for a short period, even after the image has been removed from direct view of the eye. A good example of the persistence of vision is the continuous ring of light when an electric torch is rotated rapidly in a circle.

Since the eye will retain an image for approximately 1/20th of a second, all the picture elements must be transmitted within 1/20th of a second or less if the eye is to see the entire picture all at once. In other words, the scanning process must be rapid enough so that the last scanned line of the image appears on the screen while the impression from the first scanned line of the scene still persists in the eye. In the present television system, 1/30th of a second is required to transmit all the elements contained in one complete picture or frame. However, for reasons to be mentioned later, the scanning of a complete picture or frame is broken up into two periods of 1/60th of a second when the picture is partially scanned from top to bottom during the first period of 1/60th of a second, and then the picture elements not scanned in the first period are scanned in the second period of 1/60th of a second so that the entire picture is scanned in 1/30th of a second. This method of scanning is known as INTERLACED SCANNING and will be explained in detail later.

### 7. The iconoscope or camera tube.

The iconoscope or camera tube provides the means whereby the scene to be televised is converted into a corresponding electro-sensitive image and then scanned in the manner just described, which changes the individual picture elements into electrical impulses. The iconoscope receives its name from the Greek words "icono", meaning "an image", and "scope", meaning "to see".

Figure 1-3 shows the essential parts of an iconoscope or television camera tube.

The most important element in the tube is the photo-sensitive mosaic plate upon which the image to be televised is focused through an optical lens in a manner that is very similar to the method used in an ordinary camera. The photo-sensitive mosaic plate in the television camera tube corresponds to the photographic plate or film in the ordinary camera.

The mosaic plate consists of a flat piece of mica which has millions of separately insulated particles of silver deposited upon it. Each silver particle is coated with a layer of caesium oxide, making it a photo-sensitive element possessing the property of emitting electrons in proportion to the amount of light that is focused upon it from a minute part of the image being televised. A flat conducting plate is placed on the back of the mica, which makes a small capacitor out of each silver particle with the mica as the dielectric and the conducting plate acting as a common plate for the millions of small capacitors thus formed.

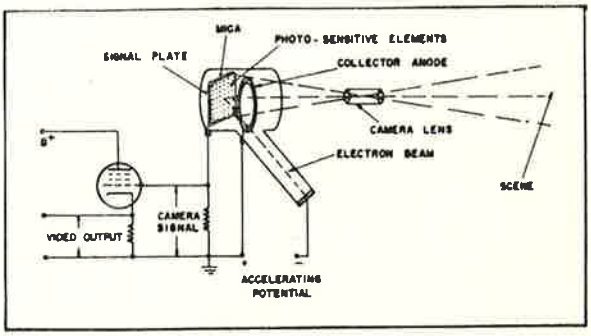


*Fig. 1-3. The iconoscope.*

The electrons emitted from the mosaic plate are attracted by the collector ring which has a positive potential and each small capacitor becomes charged by an amount depending on the intensity of light striking the photo-sensitive particle associated with it. The optical image, in this manner, is impressed electrically on the mosaic plate where each individual element assumes a charge which is proportional to the intensity of light at that particular point in the scene. This represents the first step in the process; it makes available a medium through which light units can be converted into electrical units. The next step is the dissection of the signal into very narrow strips or lines which can be transmitted in continuous sequence.

This is accomplished by means of an electron beam which scans the mosaic plate from left to right and top to bottom, under the influence of the horizontal and vertical sets of scanning coils. (The actual details of deflection will be considered later.)

As the electron beam sweeps across the mosaic, it discharges each individual photo-sensitive element as it passes over it. The discharge occurs through the common signal plate; thus, the rapidly sweeping beam causes a corresponding voltage variation in the external signal circuit. The precise character of the output voltage is determined completely by the relative charge of each of the elements which, in turn, is determined by the light intensity of the portion of the scene being scanned.

In other words, the successive values of potential on the mosaic plate are electrical impulses which correspond to the amount of brightness of the successive picture elements contained in the image being televised.

The description just given of the action taking place in the iconoscope is necessarily brief but serves to show how the image to be televised is first transformed into an electrosensitive image on the mosaic plate of the iconoscope, and is then dissected into its individual picture elements by means of scanning with an electron beam. The detailed operation of the iconoscope is considerably more complex than the description just given, however, the fundamental principle of operation is the same.

### 8. Image repetition.

Now that we have considered the basic structure of a picture and how the light and shade in the picture can be converted into corresponding electrical impulses which are transmitted one after the other in an orderly sequence and then reproduced on the screen of the picture tube, we can consider the black and white motion picture.

As is well known, a motion picture film is made up of many still pictures, each of which differs only slightly from the preceding and following pictures. Each picture or frame is held stationary for a brief period of time as it passes behind the projecting lens and the picture is presented on the screen for a short period. Then the shutter closes and the next picture or frame moves into place. As soon as the film comes to rest, the shutter opens again and projects a second picture on the screen. Because of the fact that the picture remains stationary during the time that it is projected onto the screen, no blurring takes place and consequently the slight differences between successive pictures are the only changes noticed by the eye. If the individual pictures or frames are presented rapidly enough, the picture appearing on the screen will appear continuously illuminated and any motion in the image will appear smooth and continuous due to the persistence of vision.

Were it not for this characteristic, the picture appearing on the screen from a motion picture projector would not appear smooth and continuous and the eye would notice each time the shutter opened and closed, the picture would not appear continuously illuminated, and there would be no smooth blending of one image into the other, which is necessary for the illusion of continuous motion.

### 9. Flicker.

If the frequency with which light issues from the projector is not sufficient to give the impression of steady light, a rapid fluctuation in the intensity of illumination of the screen will be seen. This fluctuation in illumination is referred to as FLICKER.

Present motion picture practice is characterized by projection at the rate of 24 frames per second, which is sufficient to give satisfactory illusion of motion but at this low rate there would be considerable flicker, especially for the higher intensities of illumination. However, in motion pictures this effect is corrected by the simple device of breaking up the projection of each still picture into two periods of equal length by the action of the shutter which projects each picture or frame on the screen twice, thus increasing the frequency of illumination of the screen from 24 to 48 times per second. The eye thus receives two light impressions instead of one during the projection of one picture or frame, and due to the persistence of vision this results in the impression of steady light. A method similar to this is used to eliminate flicker in television and will be discussed later.

### 10. Illusion of continuity of motion in television.

It was mentioned earlier that in the present television system a complete picture or frame is transmitted in 1/30th of a second. This serves the purpose of presenting to the eye, the illusion of seeing one complete picture even though the individual picture elements are transmitted one after the other. They are other reasons for the choice of 30 frames per second, which will be discussed later.

Now, if 30 complete pictures are transmitted in one second, each one differing slightly from the other as in the case of motion pictures, the eye will receive the illusion of continuity of motion and any motion in the picture will appear smooth and continuous due to the persistence of vision.

If the image appearing in the television camera is scanned in such a way that the successively traced lines are adjacent, then the entire screen of the picture tube will be illuminated once in 1/30th of a second. This method of scanning is known as PROGRESSIVE SCANNING and is not used in the present television system. Insofar as picture definition and the illusion of continuity of motion are concerned, progressive scanning would be satisfactory. However, due to the fact that the entire screen of the picture tube is illuminated only once during each frame, the frequency of illumination will be 30 times per second, which is too slow to give the impression of steady light and a rapid fluctuation in the illumination of the screen will be noticed, resulting in flicker.

To overcome this trouble, it is necessary to increase the frequency at which the entire screen of the picture tube is illuminated. This could be accomplished by increasing the frame frequency from 30 to say 50 times per second. However, progressive scanning at a higher frame frequency entails serious transmission problems, among which would be an increase in the band-width of the transmission channel of the over-all system.

### 11. Interlaced scanning.

Instead of increasing the actual frame frequency, a method known as INTERLACED SCANNING is used which has the effect of doubling the frequency at which the entire screen of the picture tube is illuminated without increasing the bandwidth of the transmission channel.

Without going into complete details, the fundamentals of interlaced scanning are shown in Figure 1-4. Instead of successively scanned lines being adjacent, they are separated by one line, since with interlaced scanning every other line of the image

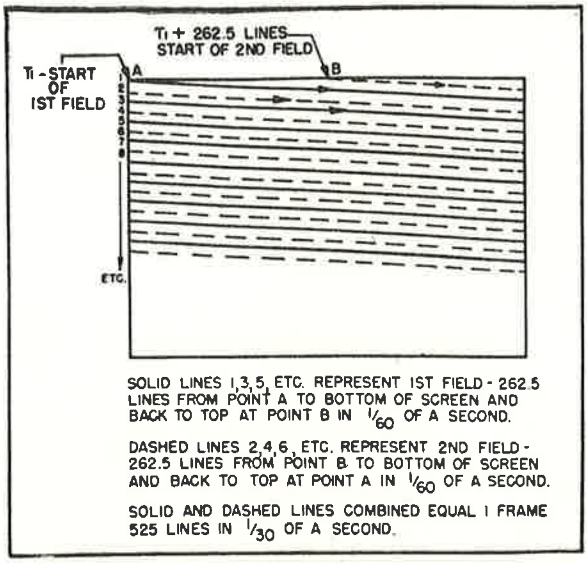


*Fig. 1-4. Interlaced scanning.*

is scanned from top to bottom in 1/60th of a second, as indicated by the solid lines which represent the first scanning period or field. These are the odd numbered lines 1, 3, 5, etc. After the completion of exactly 262.5 lines, the second scanning period starts at the top of the screen as before but this time at point B which is one-half of a line to the right of the start of the first field at point A. The rows that were omitted during the first scanning period 2, 4, 6, etc., are scanned during the second scanning period or field as indicated by the dashed lines, making a total of 525 lines scanned during the two scanning periods or fields. Therefore, at the conclusion of the second period, every point in the scene has been scanned once in 1/30th of a second which corresponds to an actual picture repetition or frame frequency of 30 per second. Each scanning period of 1/60th of a second is called a FIELD, and the two fields constitute one frame.

For simplicity, only a few of the horizontal lines are shown. When the electron beam reaches the right edge of the screen, it is very rapidly moved from right to left, however, no horizontal lines are shown for this movement, since the beam is extinguished during this period (horizontal retrace period). Also, the horizontal lines which occur during the time the beam is being moved from the bottom to the top of the screen during vertical retrace are not shown, since the scanning beam is also extinguished during this period (vertical retrace period).

By using interlaced scanning as outlined above, the entire screen of the picture tube is illuminated twice per frame, once during each field, thus increasing the frequency of illumination to 60 cycles per second, which is more than sufficient to eliminate flicker. Although the actual frame frequency is only 30 per second, the use of interlaced scanning insofar as flicker is concerned produces the same effect as though the frame frequency has been doubled, since the eye actually receives two light impressions during each frame.

Therefore, since the effective frame frequency is doubled through the use of interlaced scanning without any increase in the actual frame frequency, flicker is eliminated without any increase in the band-width of the transmission channel.

It might be well to state that the purpose of interlaced scanning is not to improve the definition of the picture; this could be accomplished by increasing the number of scanning lines with progressive scanning. The only reason that interlacing is employed is to increase the frequency at which the entire screen of the picture tube is illuminated and remove the effect of objectionable flicker.

### 12. RTMA standard definitions.

The following standard definitions of the Radio Television Manufacturers Association are in order:

A *Frame* is a single complete picture.

*Scanning* is the process of analyzing successively, according to a predetermined method, the light values of picture elements constituting the total picture area.

*Frame Frequency* is the number of times per second the picture area is completely scanned. The frame frequency has been standardized at 30 per second.

*Progressive Scanning* is that in which scanning lines trace one dimension substantially parallel to a side of the frame and in which successively-traced lines are adjacent.

*Interlaced Scanning* is that in which successively scanned lines are spaced an integral number of line widths, and in which adjacent lines are scanned during successive cycles of the field frequency scanning.

*Field Frequency* is the number of times per second the picture area is fractionally or partially scanned in interlaced scanning. The field frequency has been standardized at 60 per second.

### 13. Bandwidth requirements.

As mentioned earlier, the amount of detail in a picture depends on the number of elements making up the picture. Therefore in order to transmit a picture with good detail, it is necessary to transmit a great many impulses to reproduce all the picture elements necessary on the screen of the picture tube. A satisfactory television picture can be reproduced if approximately 200,000 elements appear on the screen of the tube for each picture. Since 30 complete frames are sent every second, this would necessitate the transmission of 6,000,000 picture elements per second.

This leads to the fact that high video frequencies are required in television transmission. A range of video frequencies extending to 4,000,000 cycles per second or 4 megacycles is sufficient to transmit a very satisfactory picture.

The value of 4 megacycles is based on the assumption that each cycle will reproduce two picture elements. This places the upper limit of the total number of picture elements that can be transmitted per second at 8 million. With the present standard of transmission of 30 complete pictures or frames sent every second, the number of elements per picture is limited to approximately 260,000. Of these 260,000 elements per picture, only about 200,000 are reproduced in the actual picture due to the necessary blanking out of a small portion of the picture during the scanning process. The details of blanking during scanning will be discussed later.

From the above, it is apparent that in order to transmit a satisfactory picture it is necessary that the entire television system from camera to picture-reproducing tube be capable of generating, conveying, and reproducing a wide range of frequencies.

Such a requirement on the video channels and the corresponding band-width requirement on radio frequency and intermediate frequency amplifiers is very severe, and special designs must be used to obtain pictures having good detail. These special features will be covered at length in a later chapter.

Unlike the regular broadcast service, it is essential that television programmes be transmitted on what is called the VERY-HIGH FREQUENCY BAND (VHF). This is necessary because the transmission of the picture elements covers far more space in the "ether" than sound broadcasting; for example, if a television programme could be transmitted at broadcast frequencies, it would require all the bands assigned to long wave, regular broadcast, police and aircraft stations to transmit a single television channel. Therefore, all the television carrier frequencies lie in what is generally called the VERY-HIGH FREQUENCY BAND.

The Federal Communications Commission has adopted six megacycles as the standard width of a television channel, which includes the audio as well as the video carrier and associated side-bands and has set up a group of channels on this basis.

### 14. Synchronising and blanking.

In addition to the picture impulses, special signals are also sent out by the transmitter for the purpose of synchronizing the scanning process between the television camera and receiver.

One group of pulses, known as HORIZONTAL SYNCHRONIZING PULSES, are used to time the start of each horizontal scanning line at the receiver with that at the television camera. A horizontal synchronizing pulse occurs at the end of each line and initiates retrace of the electron beam in the picture tube, causing it to be moved very rapidly from the right side of the screen back to the left-hand side of the screen in position to start tracing another line from left to right.

Since it is undesirable for the movement of the electron beam to be visible during the horizontal retrace period, that is while the beam is rapidly being moved from right to left, blanking pulses are also transmitted in conjunction with the horizontal synchronizing pulses which extinguish or blank out the beam during this period. These blanking pulses are applied to the control grid of the picture tube and actually bias it to cut-off or beyond during the retrace period.

A second group of synchronizing pulses known as VERTICAL SYNCHRONIZING PULSES are used to time the start of each field. These pulses occur at the end of each field and are responsible for bringing the beam back from the bottom to the top of the screen, placing it in position to start the next or succeeding field.

In order to maintain proper horizontal synchronization and proper interlacing of the lines, the movement of the beam in a horizontal direction must not be interrupted, even while the electron beam is being moved from the bottom to the top of the screen. To prevent this horizontal movement of the electron beam during the vertical retrace period from being visible, the electron beam is blanked out or extinguished by a blanking signal which is transmitted in conjunction with the vertical synchronizing pulses. The vertical blanking signal is of longer duration than the horizontal blanking signal, since the duration of the vertical retrace period is considerably longer than the horizontal retrace period.

In order for perfect interlacing to occur, each field must start at the same instant each time, that is, the elapsed time between the start of one field (Point A of Figure 1-4) and the start of the next or following field (Point B of Figure 1-4) should be identical each time. To insure this condition, another group of pulses are transmitted in conjunction with the vertical synchronizing pulse group and are known as EQUALIZING PULSES. These pulses immediately precede and follow the vertical pulse group and establish identical conditions preceding and following the vertical synchronizing pulses for successive fields.

The rate at which the vertical synchronizing pulses occur or are transmitted is 60 times per second, since a vertical synchronizing pulse group occurs at the end of each field.

The rate at which the horizontal synchronizing pulses are transmitted is equal to the line frequency, since a horizontal synchronizing pulse occurs at the end of each line. The line frequency is equal to the total number of lines per frame multiplied by the number of frames transmitted per second and is equal to 525 × 30 or 15,750 cycles per second.

There is considerably more that might be said regarding the synchronizing and blanking signals, however, for the time being at least, they will not be discussed any further. The details and exact relationship of all these signals will be considered when the standard television signal is discussed.

### 15. Lines per frame.

The exact figure of 525 lines per frame is based on the fact that the type of interlacing used requires an odd number of lines plus the fact that the figure chosen should have simple factors. The latter consideration is to simplify the generation of synchronizing signals at the transmitter; 525, for example, has the factors $7 \times 5 \times 5 \times 3 = 525$.

### 16. Lines per field.

Since exactly 525 lines are scanned per frame or every 1/30th of a second, then 262.5 lines are scanned during each field or 1/60th of a second.

### 17. Frame frequency.

All modern television systems have a frame frequency of half the power line frequency. The value of 30 frames per second satisfies two requirements: (1) A frame frequency of 30 per second is ample to give satisfactory illusion of continuity of motion; (2) A frame frequency of 30 per second is equal to half the power line frequency in most localities, and if there is any hum present in the system, it will not be nearly so noticeable as it would if another frame frequency were used.

### 18. Field frequency.

The field frequency of 60 per second is more than enough to maintain a sufficiently high frequency at which the screen of the picture tube is illuminated to prevent the effect of flicker. Also, it minimizes the effect of hum.

### 19. Aspect ratio.

The aspect ratio is simply the ratio of the width to the height of the picture and has been standardized at a ratio of 4:3. In other words, if the width of a picture tube screen is say 4 inches, then its height should be 3 inches. Likewise, if the width of another picture tube screen is 24 inches, then to maintain the aspect ratio of 4:3, its height should be 18 inches.

The aspect ratio of 4:3 is used so as to conform with existing motion picture practice and permits the televising of standard motion picture film most efficiently.

### 20. Summary.

1. Television is the systematic sub-dividing and conversion of a picture into electrical impulses whence it is conveyed to a receiver and assembled in proper order and position to form a complete picture again.
2. The picture and sound signals are transmitted simultaneously but by separate transmitters.
3. The sound transmitter is frequency-modulated.
4. The picture transmitter is amplitude-modulated.
5. A separate antenna is used for each transmitter.
6. The optical image is changed into a corresponding electrical image by the television camera.
7. The sound and picture signals are picked up simultaneously by one receiving antenna.
8. The sound and picture signals are separated into two channels at the receiver.
9. The picture reproducing device is a cathode ray tube.
10. The basic structure of any picture is the areas of light and shade known as PICTURE ELEMENTS.
11. For good detail, the picture elements should be small and numerous.
12. A typical television picture contains approximately 200,000 picture elements.
13. The television camera tube or iconoscope changes the optical image into an electro-sensitive image and then converts this image into electrical impulses by the scanning beam.
14. The electrical impulses produced by scanning of the image are transmitted one by one in orderly sequence and are reproduced on the screen of the picture tube in the same manner.
15. All the elements in the entire picture are transmitted in 1/30th of a second, which is sufficiently rapid so that the eye receives the impression of one complete picture even though the picture is transmitted element by element.
16. Television depends upon the persistence of vision.
17. Persistence of vision is the ability of the eye to retain an image for a short time after the image has been removed.
18. 30 complete frames or pictures are transmitted every second, which is more than enough to give continuity of motion to the scene.
19. If the frequency at which the screen is illuminated is low, flicker will result.
20. Flicker is corrected in the television system by the use of interlaced scanning, which doubles the frequency of illumination.
21. In interlaced scanning, the entire image is partially scanned in 1/60th of a second.
22. The rate at which the image is partially scanned is known as the FIELD FREQUENCY and is 60 per second.
23. The rate at which the image is completely scanned is known as the FRAME FREQUENCY and is 30 per second.
24. A complete picture or frame of two fields is completed in 1/30th of a second, during which time the image is scanned 525 times. During each field or 1/60th of a second, the image is scanned 262.5 times.
25. If approximately 8,000,000 picture elements are transmitted per second, a very satisfactory picture can be reproduced.
26. To transmit a picture having 8,000,000 elements, it is necessary that the entire video system pass frequencies from almost zero cycles to 4 mc.
27. Television signals are transmitted on the very-high frequency band to accommodate the large band-width required.
28. The band-width of the television channel has been standardized at 6 mc.
29. Synchronizing signals which time the start of each horizontal scanning line are called HORIZONTAL or LINE SYNCHRONIZING PULSES.
30. Synchronizing signals which time the start of each scanning period of 1/60th of a second are called VERTICAL or FIELD SYNCHRONIZING PULSES.
31. Blanking signals which extinguish the beam while it is being moved from right to left during the horizontal retrace are called HORIZONTAL BLANKING SIGNALS.
32. Blanking signals which extinguish the beam while it is being moved from the bottom of the screen to the top during vertical retrace are called VERTICAL BLANKING SIGNALS.
33. Synchronizing signals which help to maintain correct interlace are called EQUALIZING PULSES.
34. The aspect ratio of a television picture is 4:3 and is simply the ratio of its width to its height.

# Compact Back-Loading Folded-Horn Cabinet for 12" and 15" Loudspeakers

## FEATURES

- Efficiency increase over ordinary enclosures of similar size.
- Horn loading for maximum efficiency.
- Folded horn path for compactness.
- Back-loading design permits use of unitary multiple channel loudspeaker arrays.
- Hyperbolic-exponential formula maintains effective loading to lowest frequency.
- Reduced diaphragm excursion due to effective loading minimizes non-linear distortion.
- Sound chamber design gives acoustic crossover at approximately 300 cycles preventing interference between horn mouth and direct diaphragm (front-side) radiation.
- Small sound chamber yields high efficiency above acoustic crossover thus permitting higher frequency for electrical crossover in multiple channel systems without loss in m-f region.
- Designed to fit in corner to give larger apparent size.
- Effective reproduction where corner is not available.

## APPLICATION

It is generally recognized that a large horn mouth and consequent long path length are desirable for effective l-f loading. In the interest of compactness and practicality these factors have been somewhat compromised in these designs. However, much of the advantage of horn loading is still retained, particularly when used in a corner. Here the room walls tend to supplement the horn by adding apparent length with larger effective horn mouth size.

The use of a horn path contour in the hyperbolic-exponential family gives optimum loading down to the theoretical flare cutoff frequency of 43 cycles. The theoretically derived continuously curved boundaries are approximated by a series of conical or constant flare sections. At low frequencies where the wave-length is long compared to the dimensions involved such an approximation gives performance essentially identical to that for the theoretical flare.

The back-loading feature of these designs is achieved by providing a relatively small enclosure back of the loudspeaker diaphragm with the horn throat at the front of this chamber. For frequencies above approximately 300 cycles the design provides an acoustic crossover network so that radiation above this frequency is suppressed in the horn thus preventing interference with the radiation directly from the front of the diaphragm. Also this chamber gives relatively high efficiency in the frequency range above 300 cycles to balance the l-f output.

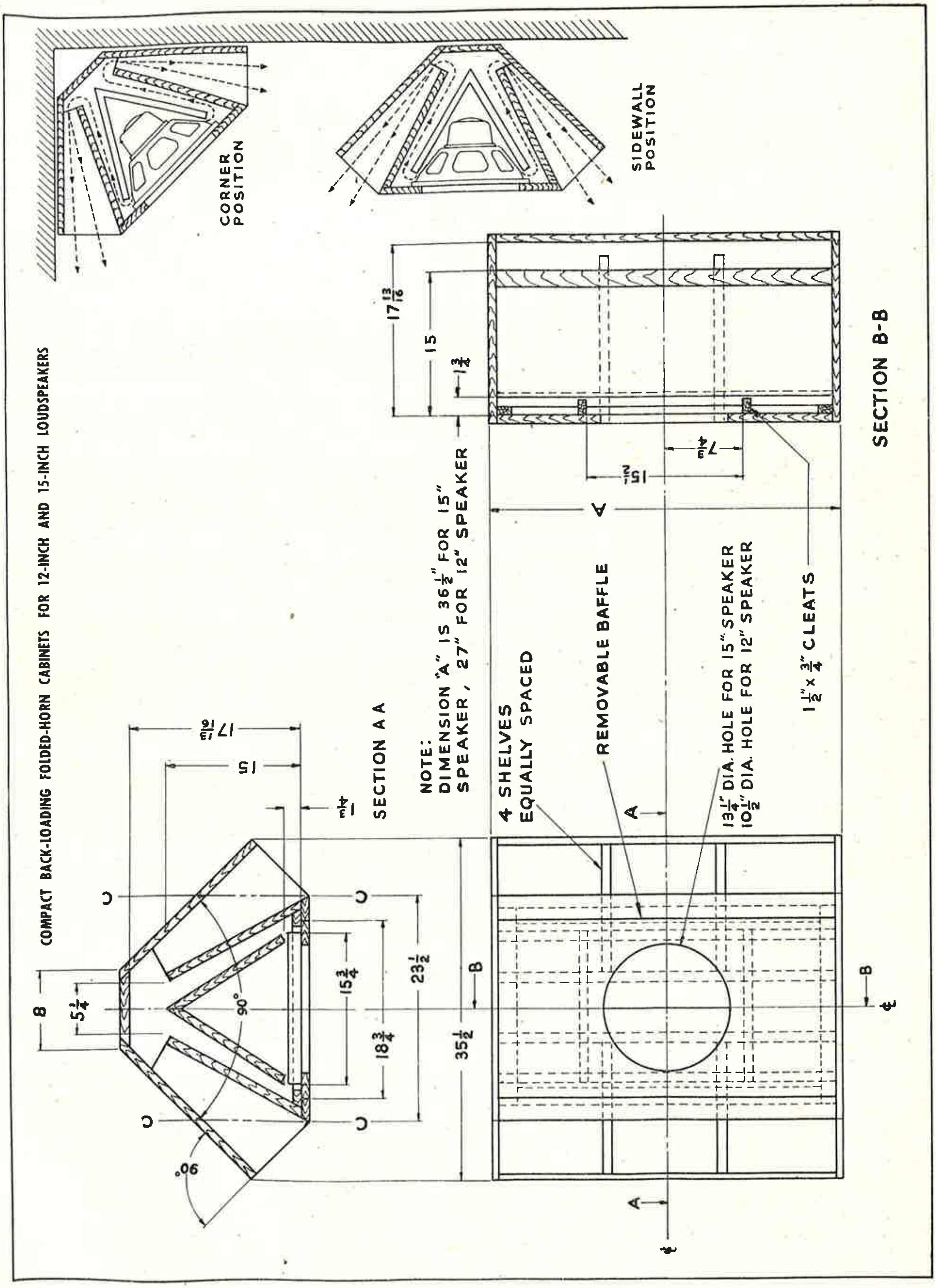
As will be apparent from the above material, it is perfectly feasible to build-in such cabinets as a permanent structure. Obviously, the walls of the room can be used for the two outside surfaces of the horn structure if the remainder of the horn is attached to the walls with airtight joints. This added flexibility may prove helpful in many custom installations.

The horn mouth openings can be covered with grille cloth; similarly, grille cloth can be used to cover the speaker openings in the baffle or the entire baffle. A porous material is desirable. In many cases metal grilles will be preferred and certainly these are functionally quite satisfactory. Expanded metal screens are now readily available and offer the least impediment to the sound waves being radiated. In some cases where both a grille screen and grille cloth are used there is a tendency for the cloth to vibrate against the screen in certain frequency regions, creating noise. It is usually not feasible to fasten the grille cloth to the metal screen except by special techniques. One simple remedy is to space the grille cloth ¼-inch or more from the grille screen.

Large obstacles, such as heavily upholstered furniture and bookcases, should preferably be no closer than approximately three feet from the horn mouth. Lamps, open chairs and the like have little effect.

## CONSTRUCTION NOTES

1. Use good quality ¾" plywood panels with the particular veneer you desire on all exposed surfaces.
2. Construction must be rigid; use additional bracing if necessary. Tapping of any panel with mallet or fist should result in a solid thud rather than a "drummy" sound. Panel vibrations can result in 3 to 4 db loss at certain frequencies.
3. Joints must be airtight, particularly near the loudspeaker. Air leaks will decrease efficiency at the lower frequencies due to pressure loss. Use wood screws and glue joints wherever feasible.
4. Lay out all parts carefully before cutting to prevent wastage.
5. Do not scale drawings; angles should be calculated or measured from full scale layouts.



COMPACT BACK-LOADING FOLDED-HORN CABINETS FOR 12-INCH AND 15-INCH LOUDSPEAKERS

NOTE:
DIMENSION "A" IS 36½" FOR 15" SPEAKER, 27" FOR 12" SPEAKER


AWV