MECHANICAL VS. CATHODE TELEVISION SYSTEMS

Comparative cost, size, complexity, efficiency, features, and physiological effect on the person viewing the image, are discussed.

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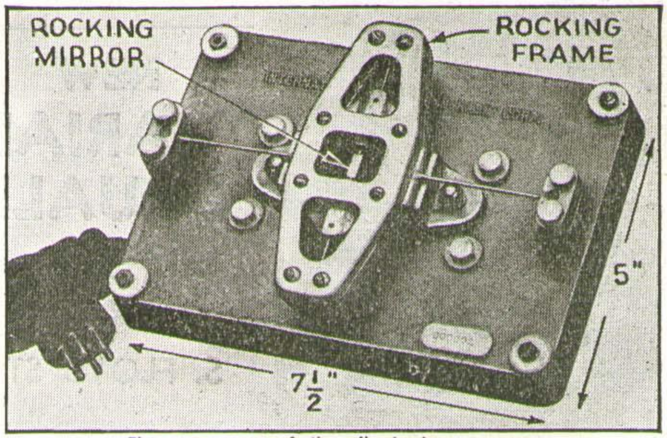
THERE IS a great deal going on in television that is new even to the workers who have been long immersed in the problems of the laboratory. These new developments are mainly in the theoretical state; such for example, as the flying spark, the oscillating crystal and the multicellular systems. It is reasonable to say that they add ideas to the television art, which had borrowed much of its thought and equipment from many other arts, but nevertheless it is also reasonable to say that as we view the picture today, the race is to be run and *the winner is to come from one of two schools.*

TWO SCHOOLS OF TELEVISION THOUGHT

These two schools are represented by the advocates of (1) *the Braun cathode-ray* and the advocates of (2) *the mechanical systems.* In particularizing the reference to the cathode ray, I refer to its inventor Braun, who dates back almost as far in the art as does Nipkow, pioneer among the devisers of mechanical systems. So little attention is given to this German scientist Braun that I find many television engineers seem unaware of his vital contribution.

We all know that whichever system—the Braun cathode-ray or the mechanical system—proves the best commercial answer to the problem, this system will be ultimately adopted, because television inherently is, and must be, built on a single pattern; a single type, that is, insofar as the technical equipment is concerned. That there will be considerable waste of investment in order to make this choice, seems to be inevitable. Whoever buys a receiver based on the cathode-ray principle will be left holding the bag should the mechanical system become triumphant. Likewise will this be true in the case of all who buy receivers built on the mechanical principle should they at a later date find that the cathode-ray system is adopted.



The appearance of the vibrator-type scanner.

As far as the investment in transmitting equipment is concerned, no tears need be shed in either case, because transmitter installations will be of sufficient flexibility to enable them to be altered to another form of system at a comparatively minor expense. Personally I believe in the *"vibratory" mechanical system* and cannot conceive how the cathode-ray system will be eventually triumphant.

Fundamentally all television sets have many parts and

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functions in common. They are primarily differentiated by the way in which they scan or sub-divide an object at the transmitter, and the form of scanning they employ at the receiver to reassemble the picture from the received electrical pulses. Therefore our first point of inquiry should be directed at the comparison of the two types of scanners.

CATHODE-RAY AND MECHANICAL SCANNER FUNDAMENTALS

The *cathode-ray* system employs a large evacuated glass tube on the end of which is a fluorescent screen, and upon this screen a fine cathode-ray "pencil" paints a picture. The illumination comes directly from the power of the cathode-ray beam. The beam travels over a predetermined geometrical pattern under the influence of two spaced pairs of scanning electrodes. A number of large radio and electrical companies in the United States have been working on the cathode-ray system for the past 6 years and have spent vast sums on its development.

In the *mechanical* systems there is a physical motion of one or more parts. The light from a steady source modulated by a Kerr cell is projected from a moving optical element to a screen. The mechanical motions used are either rotary or oscillatory. The former has been generally abandoned because of the multiplicity of optical systems it requires and the resulting high cost, leaving for practical consideration only the oscillatory or *vibrating* type. The scanner shown in the heading illustration is the Priess scanner and is of the vibrating-mechanical type. Dr. de Forest has told me he believes it to be the only satisfactory high-definition scanner so far devised. (Additional illustration and description of this unit appear on pg. 123 of the August 1935, Television Number of *Radio-Craft.—Editor*)

In the following, I am setting down the claims made by the cathode-ray and vibratory-mechanical systems, in the hope that they will give the public an insight into the relative merits of the rival systems.

DEFINITION

The quality of a television picture is dependent directly upon the number of areas into which the subject is broken, providing that the pictures are repeated with sufficient rapidity to give a smooth continuity. Other than the scanner itself there are 2 factors that limit the detail or the dot frequency. The first is the width of sideband that the Federal Communications Commission is likely to permit, and the second one is a technical limitation imposed by the amplifier in the receiver. This latter limitation is serious and for an amplifier of high gain within the low-cost class we might set its upper range at about 2 megacycles. Of course with time this range will be extended.

Both the cathode-ray scanner and the Priess mechanical scanner can be built to the upper limit of the amplifier range and beyond.

There is no real upper limit to the rate at which a cathode-ray tube can be made to scan, but this property is of little value because its practicability is blocked by the amplifier. Such a claim as "1,000 lines" is misleading, for the amplifier to which the tube must necessarily be connected will not pass more than 250 lines! And again, if such an amplifier could be built, the sidebands required would be so great that the Federal Communications Commission would hesitate about the allocation of such a huge slice of the ether to a single station.

As a practical matter therefore, the detail or quality of both systems is the same. Other systems which cannot meet this standard of quality, fixed only by the amplifier limitations, have no place in home television.

PICTURE SIZE

The size of a cathode-ray picture is limited by the size of the evacuated tube which carries the screen upon which the picture is painted. Pictures 6 x 8 ins. and some 8 x 10 ins. are shown. Larger pictures about 12 x 14 ins. are produced by the combination of an optical system in conjunction with a tube operated on high pressures of 5,000 to 10,000 volts.

The mechanical system operates on a simple projection principle, that is to say that the field of light subtends a solid angle whose apex coincides approximately with the vibrating optical element. Since this angle can be readily made 20 deg. (for a 5 deg. motion of the optical element on either side of the neutral strain position), pictures 3 ft. on a side can be projected at a distance of about 6 ft. from the scanner!

This difference in picture size, that is to say the inherently small size of the picture produced by the cathode-ray, and the large picture produced by the mechanical system is a point of very great importance. I do not believe—other things being equal—that the public will choose a small picture system when they have the opportunity of purchasing a large picture device. They have been trained to theater and home movies. These are the standards upon which their judgment is based. Can anyone imagine a typical movie fan spending an evening peering through an old-fashioned peep-hole machine of the variety found in the shooting galleries, in preference to enjoying a modern projected picture?

PICTURE BRILLIANCY

The illumination of a cathode-ray picture is a function of the impact energy of a stream of electrons upon a translucent fluorescent screen.

The illumination of a mechanical picture is a function of the brightness of the steady source of light and the area of the vibrating optical system.

The factors that limit the brightness of a cathode-ray picture are of great interest. Since the screen must be translucent, the deposit of fluorescent material must be thin. If the voltage applied to the tube is pushed up to increase the brilliancy, the violence of the bombardment of the screen rapidly destroys it. Furthermore all of the power for the illumination must come from an amplifier that is flat from a low frequency to the limiting frequency of a scanned dot. This power is most expensive and requires a large amplifier output at peak pressures of several thousand volts. In other words, the limits are set by the burning-out of the screen on the one hand, and the cost of the apparatus for producing a very high voltage of broad band characteristics on the other. However, the brilliancy is adequate for the small-size pictures now produced, but is distinctly inadequate for a substantial optical expansion of the picture.

The mechanical system functions in an entirely different manner. The light is steady; and supplied from an inexpensive power source. Only a small amplifier power is required to modulate it; and this power is delivered at medium potentials. One limitation to the brilliancy is the intensity of the source. There is available an enclosed source that has a brightness greater than that of the disc of the sun. This lamp is small and inexpensive, and has a long life. (See the article, in this issue of *Radio-Craft*, by Dr. de Forest.—*Editor*) The second limitation is the area of the moving optical system upon which the beam impinges before being projected to the screen. Using the mentioned light source and a mirror of 3/16-sq. in. with an optical system of an overall efficiency of about 22 per cent, the illumination is adequate for a 3 ft. picture; smaller pictures are correspondingly brighter. The 3/16-sq. in. size mirror requires 1A. at ½-V. to drive it. Larger mirrors can be used with a corresponding increase of driving power.

The story is not told completely by merely comparative brightness. The quality of the light and its physiological effect enter. The picture produced by a cathode-ray tube is usually a green-gray. The picture produced from the mechanical system using a steady light source modulated by a Kerr cell is generally white-gray to white-black. The cathode-ray picture tires the eyes and causes the observer after prolonged programs to find his eyes recording drifting spot areas when viewing objects other than the picture. This phenomenon does not occur with the mechanical system, that is to say, with the mechanical system the physiological effect is the same as that resulting from viewing an ordinary black and white motion picture.

Generally the lighting problem favors the mechanical system in respect to the unit screen brilliance for equal screen areas, the amount of broad-band power required for a given illumination, the life of the respective screen element, the potentials that must be generated by the amplifier, and the physiological effect.

SCANNING CIRCUITS AND SYNCHRONIZATION

Both systems drive their scanning on amplifier power controlled by a modulation of the carrier wave. In the case of the cathode-ray system, the scanning is performed by applying 2 high potentials of the order of 1,000 V. to corresponding pairs of electrodes, or in other words by electrostatic control. In the mechanical system the scanning is performed by supplying 2 magnet systems with a predetermined number of ampere turns excited at potentials of the order of only 10 V.! It is much less expensive to construct supply circuits of low voltage than it is to build corresponding circuits of high voltage.

But there is a more basic difference involved. The cathode-ray beam is practically inertialess and follows exactly the shape of the wave impressed upon its control electrodes. If this waveform varies from the pattern employed at the transmitter a corresponding picture distortion is introduced.

In the vibratory-mechanical system *the motion is harmonic* as are all of man's other recurring, predefined, constant-time-interval mechanisms. The scanners have an inherent period in each direction, dependent upon the designed moment of inertia and cooperating elasticity of each of the systems of motion. In operation they have a comparatively tremendous amount of energy stored up when compared to the increment of energy supplied by each driving pulse. They automatically tend to keep in step with the transmitter, and the waveform of their driving power is of no consequence upon the matter of picture distortion due to this great energy storage. It must be borne in mind if there is a slight difference in the natural periods of the scanners, that under the influence of a driving pulse on each swing, they will follow the period of the driving pulse and not their own, slightly off-resonance natural period. With a control of amplitude and phase at the receiver an exact framing and synchrony can be obtained.

The type of driving power favors the mechanical system. Furthermore, in spite of the variations that may be introduced by off-resonance, which variations can be compensated for at the receiver, the inertia inherent to the mechanical system eliminates a cause of distortion to which the cathode-ray system is sensitive—that of reproducing every slight ripple and surge in the base timing (scanning) voltage—because its beam lacks elasticity and inertia.

COMPARATIVE COSTS

It is not quite in balance to compare the cost of a small cathode-ray picture with the cost of the large picture produced by the mechanical system. However, cost is a vital factor and must be considered at least on the basis of the physical receivers that both systems propose to offer the public.

Starting with the scanner, the cathode-ray tube, like an incandescent lamp, is consumed while it operates. The vibratory-mechanical scanner, somewhat like a telephone receiver, has an almost unlimited long life. It has no bearings or sliding parts. The factory cost of the former including shrinkage is about $20.00 and the latter about $4.00.

The amplifier for the cathode-ray tube must supply 3 high-voltage circuits with *accurate* waveform power, with one of the circuits drawing all the lighting energy at frequencies between the bottom of the range and say 2 megacycles. The amplifier for the mechanical system likewise has 3 circuits, but only one of these must be of high fidelity over a broad band and that one is of medium output and voltage. The other two circuits are very low voltage and can be of any waveform. I would roughly estimate the cathode-ray system amplifier at about 3 times the cost of the amplifier for the vibratory-mechanical system. The latter should cost about $45.

In addition to this equipment the mechanical system requires a source of light, a Kerr cell and a screen. These items should cost about $10.

To sum up, the retail selling price of a cathode-ray receiver for a small picture, that is to say 6 x 8 ins. would be about $550. The retail selling price for a mechanical system receiver producing a 3 x 3 ft. picture would be about $200.

GENERAL

In the technical and commercial race between the two systems, the mechanical has the distinct advantages of picture size and cost. But what of the fragility of the big and expensive cathode-ray tube, and the danger of bringing high-voltage circuits in the home where busy little mischievous hands may cause tragedy? (This possibility is minimized in commercial practice by incorporating switches that automatically disconnect all high voltages whenever the doors to their housings are opened.—*Editor*) The cathode-ray television system is a monumental achievement, created from the contributions of numerous talented engineers and inventors with the expenditure of many millions of dollars. But in my opinion, although it is a rare technical success it is not a commercial answer to the problem, but more accurately a bridge from the pioneer Nipkow rotors to the vibratory-mechanical scanner.

Looking ahead, I expect commercial television in the home *in color*. Can the cathode-ray system look forward with confidence to the development of a picture in color with commercial home apparatus? (See "Color Television with Cathode-Ray Tubes!", pg. 105, in the article by Allen B. Dumont that appeared in the August 1935, Television Number of *Radio-Craft*.—*Editor*) The mechanical scanner can do the job with the use of 2 carriers and a single scanner!