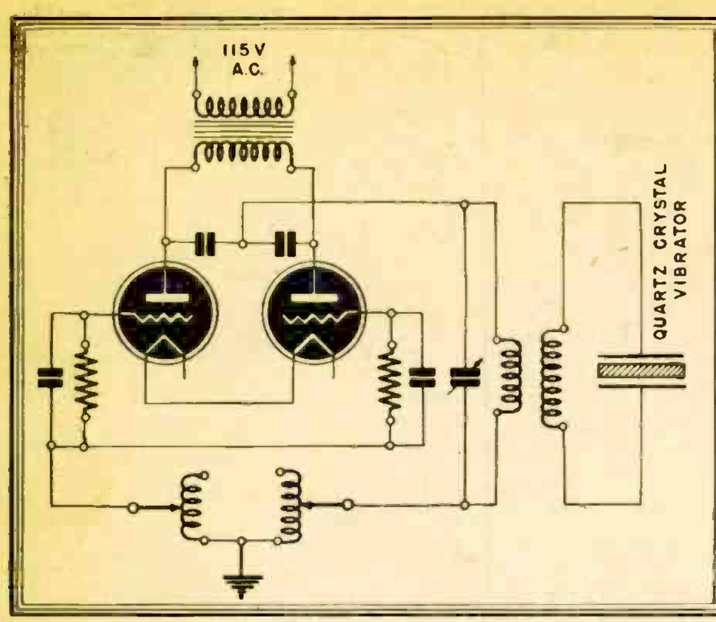

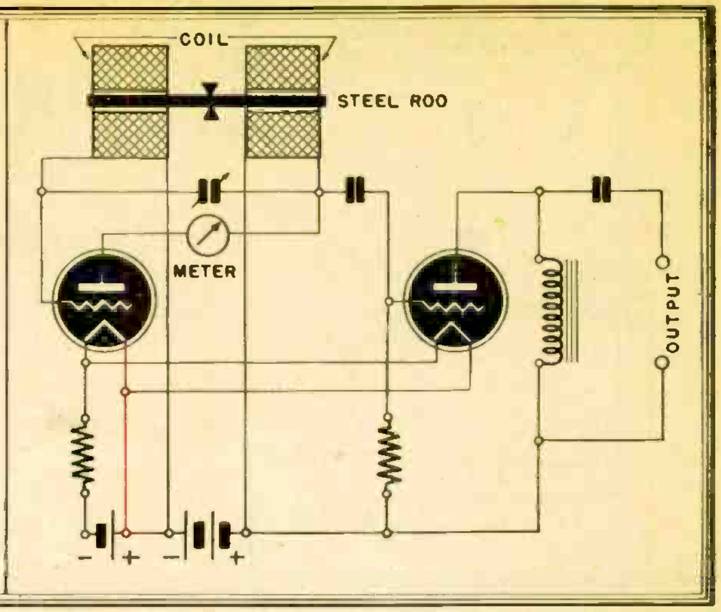

Fig. 1, left—A crystal circuit for producing supersonic oscillations. Fig. 2, right—The magneto-striction circuit for the same purpose.

Industrial Electronics

PART VI — SUPERSONICS

By RAYMOND F. YATES

THE province of sound has long since been invaded by the electron in its conquering march through the arts and the sciences. Aided by electronic devices, sound has turned out to be an important source of a new and mysterious form of energy. Sound is not only amplified by the aid of the electronic tube but it is created by it, in a large range of frequencies. The recording and reproduction of the human voice and music amounted to little until the electronic tube began its long and useful career in telephony and radio. Indeed, if we stop to think about it, a very large portion of the electronic business of today involves the amplification, recording, reproduction and radiation of sound. These are the ordinary, run-of-the-mill applications. Not so well known is the new and fascinating supersonics.

It is easy to produce electrical vibrations of a very high order. With short-wave oscillators, electrons can be made to swing back and forth in circuits millions of times a second. However, we have no sound reproducing apparatus that would respond to these prodigious speeds. If we should let such currents flow through an ordinary loud-speaker, nothing but silence would prevail. In the first place, the diaphragm of the loud-speaker would be too bulky and massive to respond to these rapidly-moving currents, and even if it were able to respond, the human hearing apparatus would not be able to detect the sounds produced. Twenty thousand vibrations per second represents the absolute limit of the capacity of the human eardrum.

In his search for a "loud-speaker" that would dance to the tune of these ultra-rapid vibrations, Professor Robert W. Wood, of the Physics Department, John Hopkins University, turned to the use of quartz crystals. It is a well known fact that a plate of quartz, cut from a crystal in the proper direction, has the property of expanding and contracting under the influence of a periodic electrical field which may be supplied by two thin metal plates in contact with its opposite surfaces and joined to the terminals of a high-frequency electrical oscillator of sufficient power. Calculations show that a quartz crystal or plate 1 cm. in thickness will respond to a natural frequency of about 300,000 vibrations per second. Consequently, if the crystal is placed in a circuit of powerful electrical oscillators tuned to the same frequency, resonance occurs, and the amplitude of the vibrations of the quartz crystal becomes very great. It is by the use of a crystal of this type that Professor Wood was able to study the mechanical effects of such astounding rates of vibration.

SUPER-SOUND WAVES

The "silent" sounds produced in this way are capable of many curious feats. A glass tube, vibrated at a rate of 300,000 oscillations per second, will sear the flesh of the fingers if it is squeezed tightly. Benzol on water is thrown into such violent action that it is driven off into the air as fine mist or smoke. Frogs swimming in liquids vibrating at this high rate are killed, and glass tubes eventually succumb to the supersonic frequencies that disrupt the ordinary molecular organization.

While ordinary quartz crystals such as those employed in amateur transmitters may be made to vibrate at super-audible frequencies by the use of a small oscillator, the amplitude of their vibrations is very small and unsuited for the work which Dr. Wood undertook. To obtain sufficient intensity, a 2-kilowatt oscillator which had originally been designed for an induction furnace was used, together with a bank of oil condensers and a large variable air condenser used with several pairs of coaxial coils for raising the voltage. The primary coils were made up of from 7 to 20 turns of Litzendraht cable, the resulting coils varying from 16 to 20 centimeters in diameter. The secondary coils, wound on glass cylinders and containing from 100 to 250 turns, were mounted within the primaries.

Equipped with this generator of supersonic frequencies, a diagram of which is illustrated in Fig. 1, Professor Wood set out to explore the wonderland of sounds that burn and explode. By the use of this apparatus with a quartz crystal cut to suitable size, sounds—if they may be called sounds—were generated with frequencies of from 100,000 to 700,000 cycles per second. The plates, which were in the form of circular discs, rested on sheets of lead

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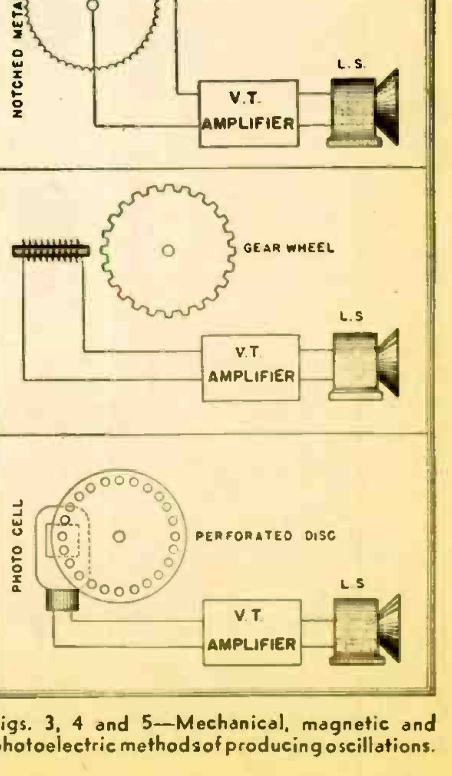
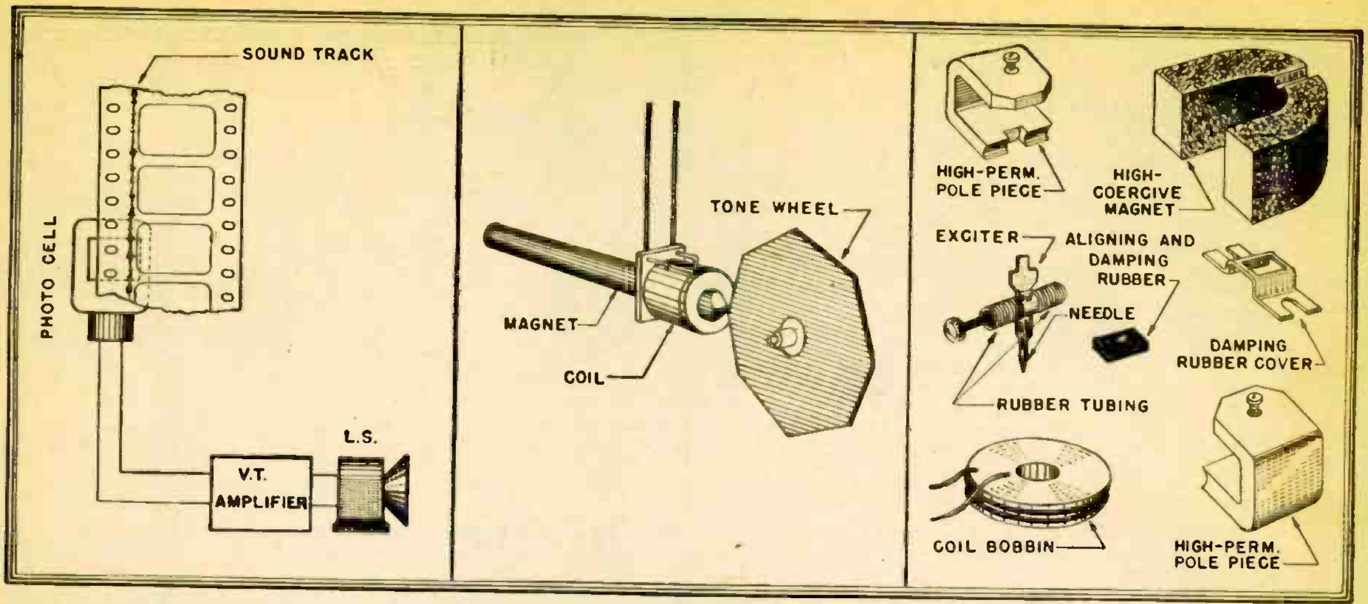


Figs. 3, 4 and 5—Mechanical, magnetic and photoelectric methods of producing oscillations.



Producers of sonics, or sound. Fig. 6 is the Movietone system, Fig. 7 the tone-wheel of a Hammond organ and Fig 8 a phonograph pickup.

at the bottom of a dish of transformer oil. The top electrode, which was formed by a disc of very thin sheet metal, rested on the upper surface of the quartz.

It was during his early researches that Professor Wood found that it was necessary to immerse the quartz in oil, to accommodate the potential of 50,000 volts generated by the powerful oscillator. With the use of such high voltage, it was found impossible to produce the effects outlined without the immersion in oil. Not only would there be sparking around the edges of the electrodes but the quartz plate would be broken to pieces as a result of the extreme vibrations induced in it by the action of the currents. By immersing the crystal in the oil bath, sparking was overcome and part of the energy imparted to the crystal was sufficiently dissipated by compressional waves in the oil. Even with this arrangement, Professor Wood was always on the borderland of danger; for it was found that increasing the voltage much beyond 50,000 resulted in a loss of crystals.

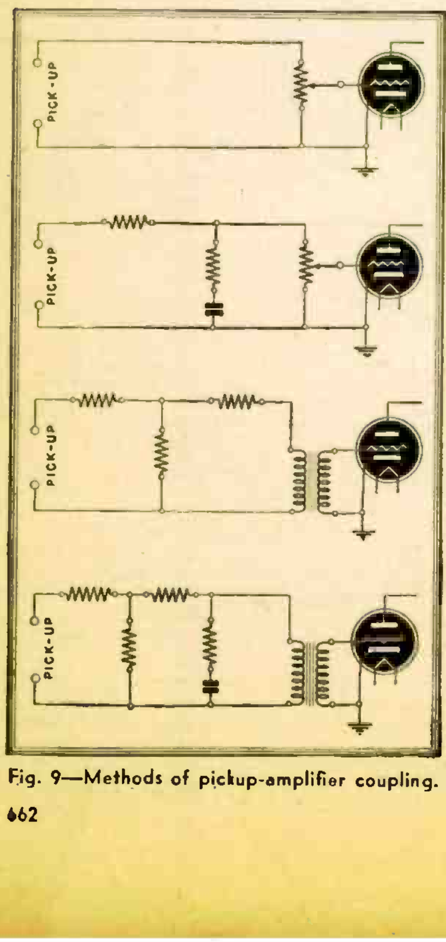


Fig. 9—Methods of pickup-amplifier coupling.

STRANGE EFFECTS OF SOUND

A beaker of water lowered to a point beneath the surface of the oil demonstrated a most remarkable phenomenon. The supersonic frequencies at which the molecules of oil were responding was instantly communicated through the glass to the water in the beaker. The surface of the water was at once pushed up into a mound, while millions of infinitesimal air bubbles appeared in the fluid. When water is heated, precisely the same effect is produced; there is a rapid movement of dissolved air in the form of bubbles to the surface of the water. In this particular case, however, the bubbles did not go immediately to the surface but became entrapped in the nodes of the standing waves which had been formed by interference from the direct waves with those reflected down from the surface. When subjected to the same process, mercury was blown into clouds of fine particles projected up through the water, which soon became as black as ink.

Maximum heating effects were produced with a small flat-bottomed conical flask drawn out to a rod of about ½ millimeter in diameter at the top. The flask was mounted on a solid support in a vertical ring and pinion device, and the distance between the flask and the crystal plate could be accurately adjusted. By bringing pine chips in contact with the top of the rod, these were caused to emit sparks and holes were burned through them.

When a chip of wood was pressed tightly against a glass rod in contact with the sound generator, the rod was set to vibrating at high speed, and the chip burned. When the same glass tube was permitted to come in contact with a plate of glass, it pushed its way through, displacing the glass in the form of fine white powder. By dusting circular glass plates with lycopodium, and subjecting the plates to the ultra-rapid vibrations, the powder arranged itself in symmetrical forms having a lace-like appearance.

Among other interesting experiments performed by Dr. Wood was that of drawing out a glass tube and spraying the constructed area with oil. When exposed to the vibrations by placing the bottom of the glass tube in contact with the rapidly vibrating supersonic generator, the oil escaped into the surrounding atmosphere in the form of fine mist or spray, which fully demonstrated the exceptionally violent action into which the molecules were thrown.

Perhaps the most interesting experiment of all these many experiments was that which tested the biological effect produced by the vibration. Red blood corpuscles were completely destroyed and the salt solution in which they are suspended quickly lost its turpidity and became a clear, red color very similar to the solution that would be produced by analine dyes. Unicellar organisms, such as paramecia, were almost instantly dispatched and the cells torn open.

Supersonics will one day find use in medicine, perhaps in surgery and certainly in chemistry and biology. The diagram, Fig. 1, does not represent the only method used in the creation of supersonic waves. There is also the magneto-striction oscillator based on the 1863 discovery of Phillip Reis who found that steel or iron rods changed their lengths or expanded and contracted to a slight degree when magnetized. Thus alternating current or modulated direct currents made such rods vibrate in a microscopic sense.

PRODUCING SUPERSONICS

When an iron rod is arranged concentrically within the two coils as shown in Fig. 2, sound generation may be carried to a very high point. As those familiar with the simple regenerative circuit will see that this magneto-striction circuit, developed by Dr. G. W. Pierce of Harvard University, is essentially an Armstrong circuit.

Other means for the generation and magnification of sounds by electronic means are illustrated in Figs. 3 to 6. The first method is purely electrical rather than electronic but the other methods involve electronic amplification. The one shown in Fig. 4 may be duplicated experimentally by revolving an ordinary gear wheel near the poles of a sensitive telephone receiver. A second telephone receiver connected to the first will give off sound, the frequency of which will depend upon the number of poles (teeth) on the gear wheel and its r.p.m.

This very principle has been applied in the Hammond and other electronic organs. The actual rotor of the Hammond machine is illustrated in Fig. 7. This peculiar shape is used to generate a precise wave form. Current from the simple generator shown

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INDUSTRIAL ELECTRONICS

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is carried to a powerful amplification system and loud-speakers.

The method shown in Fig. 5 has been mentioned in our previous reference to the photoelectric cell. This system has also been used in experimental organs and other electronic musical instruments.

The reproducing system shown in Fig. 6 employs photocells and sound photographed on the edge of movie film. This may be done either by the variable density or the variable area method.

RECORDED SOUND

Of vast importance to the young student of electronics is the recording of sound on wax discs. The sound is not only recorded electronically but is also reproduced electronically. The music or voice reaching the recording microphone is first amplified and then carried to an electrodynamic stylus or cutting head pressing down on a revolving disc.

Reproduction employs a pick-up which is really very much like the cutting head. Here a needle contacts the sound grooves and carries the vibrations to a reed armature magnet set inside a field coil. The device is really a dynamo save that the armature vibrates in place of revolving. The small current generated in the field coil is carried to powerful electron tube amplifiers. A disassembled magnetic phono pick-up is illustrated in Fig. 8. The several different methods used in connecting pick-up units to amplifiers are illustrated in Fig. 9. Proper impedance relationships must be established, along with a minimum of scratch noises.

THE UNIT OF SOUND

Some years ago, the able physicists of the Bell Telephone Laboratories found themselves in need of a scientifically justified unit for the measurement of sound. The electrical engineer had his volts and amperes, the mechanical engineers had foot pounds and horsepower, but there were nothing but leaky buckets into which bundles of sound energy could be poured. A unit called the bel, in honor of Alexander Graham Bell, was developed. Appropriately enough, the bel was used to calculate the rate at which telephone signals faded when they were called upon to survive the electrical intricacies of modern circuits. One bel represented a sound strength ten times above an arbitrary zero level, two bels an intensity 100 times zero level, three bels 1000 times, etc., on up the scale. Zero marked, not the end, but a definite limit like the zero mark on the centigrade and Fahrenheit temperature scales. The bel was more or less cumbersome when used to measure very small differences in sound level that could not help but prevail in a continuous spectrum. The decibel, which divided bels into tenths, was therefore introduced. This is the standard yardstick used in sound today. On an energy basis, a decibel represents a fraction of a millionth of a watt. It is only when we measure ordinary sounds that we are able to fasten some meaning to the unit. Today, we have sound meters that give decibel readings. A rustling leaf generates 20 decibels of sound, a lion roars at 95 decibels, a riveting hammer has a 105 decibel clatter. Beyond 130 decibels, we reach an area where nerve response degenerates into severe pathological disturbances and sound may stimulate pain, even succeed in bringing about disruption of organs.

Sound, long regarded merely as some kind of a vague atmospheric disturbance through which we hear, has finally entered the world of everyday affairs. It has assumed sociological and economic importance. The nerve-bedeviled fellow twitching in his subway seat is partly a product of the sound that assails him. His anxiety neurosis is not caused entirely by the market, his job or his boss-ridden office. Sound, too, leaves its mark, makes him a more inefficient producer. He suffers shell shock each day of his existence and his employers, his city officials, are becoming anxious if not worried over the matter. Many of our large cities are now having sound surveys made in which the meter calibrated in decibels is used to trace down and condemn the chief offenders. Manufacturers of electrical appliances and moving machinery, quick to sense factors in the popularity of their products, are also busying themselves in an effort to cut the noise produced by their products to a minimum and thereby contribute to the well-being of those who use their equipment.

We ride in airplanes, automobiles and railway coaches that have been OK'd with decibel meters; we are beginning to use electric fans, vacuum cleaners and washing machines that have been reared within the measuring ears of decibel meters. The Noise Abatement League would have every manufacturer mark his machine with the decibels of noise it produces. Should sound enter the competitive field, the public would rapidly become sound-conscious and demand a minimum of unwanted noise with each thing it bought. London has already demanded that motorists refrain from blowing horns at night and Mussolini decreed "silent days" and threatened to remove the confines of Rome factories that violate the limits of ordinary endurance. Factory owners in this country also have found that they owe it to their employees and their output to minimize noise. A man working a noisy adding machine will make more mistakes than a man operating a quieter one. Mechanical engineers, for the first time, have been called upon to develop machines that will not shatter the nerves of those who attend them.

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Radio's contribution to the war effort in 1943 exceeded $202,150,000 in station and network time, the National Association of Broadcasters reported on the basis of monthly reports from station members and OWI allocations.

Calculated on one-time rates before discounts and commissions were deducted, the radio time provided by individual stations totaled $96,506,000, while networks supplied $105,644,500 worth under the spot and special assignment plans.

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Mr. L. A. Cleaveland, foreman in the radio and test department at American Export Airlines, uses a barber chair with the back, seat and arms removed as a test stand for automatic direction finders.

A platform was built where the seat would be and a superstructure added to house the automatic direction finder. The base of the chair was used as the compass and the 360 degrees marked off on it. A pointer was affixed to the platform and bent to point to the degrees of the compass.

The equipment was placed in a shielded room and an aerial run from 0 to 180 degrees made. The equipment thus checks the instruments perfectly.—*J.R.Y.*