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Wave Motion and Modern Developments in High Frequency Electricity.

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Read at the Exhibition of Non-Ferrous Metals, Agricultural Hall, London, N.,

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Chairman: Mr. JOHN McLAREN (Member of Council).

Discussion and Demonstrations at 58, Romford Road, Stratford, on December 2, 8 p.m.

In bringing the subject of wave motion before the members of this Institute, I think it can be safely assumed that not only does wave motion enter into the daily life of a marine engineer, as into that of others, in the direction of seeing, hearing, etc., but that it also plays an all-important part in the profession which he follows, manifesting itself as heat, propelling his machinery, light illuminating his path, sound conveyed, by many wonderful means, all of which can be classified as directly associated with the marine engineering profession.

To-day great strides are being made in the science of " Wave

Motion," and hour by hour, oscillations, vibrations, and wave motions are being discovered intimately associated with all phases of scientific investigation, and one begins at last to realize that nothing is still, in the universe, and the scientist brings us to realize that even the pleasurable sensations of life associated with the human senses are all phases of this wonderful phenomenon.

Realizing, therefore, the magnitude of the science, let us endeavour to obtain some elementary idea of wave motion. This can best be explained by the assistance of a mechanical model which we have before us. It consists of a shaft carrying a series of eccentric pulleys actuating an equal number of rods, to the end of which glass beads are attached to indicate the motion more plainly. It will be noticed that the rods are elevated and depressed in turn, and in regular order, so producing a wave effect.

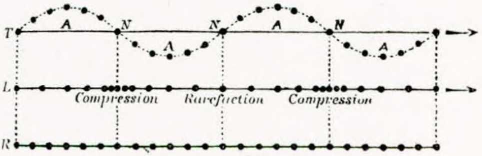
The definition of wave motion as given by Fleming is as follows :—" A wave motion can be said to exist in a medium when each portion of it executes in order along a line any kind of cyclical or repeated motion, the particles performing the motion one after the other, and with a certain assigned delay between the adjacent particles as regards their stay in the movement." From the above, it is obvious that there are many forms of wave motion, and a further reference to our experimental table at least reveals two distinct types. In the first model, it is noticed that the movement of the beads is up and down, while the wave motion is horizontal, the particles in motion moving at right angles to the direction in which the wave is propagated. This is a type of transverse wave, and it is possibly the most familiar to those who make the sea their home, for to this class belong surface waves in water, also the wave motion set up in a rope by a sailor when he gives it a sudden jerk. Again, by referring to model No. 2, we have a wave motion formed where the vibrating motion of each particle of the medium is executed in a straight line and in the same direction as the waves are propagated. This is a form of longitudinal wave motion.

Now note the construction of the model. It consists of a copper wire spiral some six to eight feet long, suspended by means of double threads from suitable supports.

Beads are attached to each convolution of the spiral to more clearly indicate the wave motion ; and with such an apparatus as this a very clear idea of wave motion is to be obtained—such wave motion as is set up in air, ether, or any such similar medium. Fasten one end of this spiral to a hollow box, and give the other end a sharp blow; it will be noticed that the blow is carried along the wire and the box experiences a sharp rap.

This firmly illustrates that wave motion is not merely the motion of a particle, in a peculiar and interesting manner. It plays a much more important part in the scheme of the Universe. Wave motion is a means of carrying energy.

Referring to Fig. 1, we have a diagram representing a transverse wave, and from this diagram we will deduce the various definitions, etc., associated with this science. Note that



–TRANSVERSE AND LONGITUDINAL WAVES.

FIG. 1.

certain particles are moving in the same direction at the same rate and from similar positions on the wave line. These particles can be said to be in the same state of motion. The distance is termed the "wave length." The wave length is more aptly defined as the distance between two particles of the same phase.

Again, when a particle has made one complete vibration, that is from its normal, the wave crest has moved forward a distance equal to the wave length. Therefore, the wave length equals the distance through which the crest travels in a line required for a complete vibration.

The definite distance a particle moves from its normal, or mean position is termed its "amplitude." The "frequency" is also defined as the number of vibrations in unit of time.

The relation between wave velocity, length and frequency is stated as follows :—

Wave velocity = wave length and wave frequency.

Note.—From consideration of a vibrating pendulum.

$$\text{The velocity number} = \frac{\text{Time}}{\text{Period of vibration}} = \text{N} = \frac{1}{\text{T}}$$

As a wave moves through a distance equal to a wave length in the time required for one vibration T,

$$\therefore \text{ Velocity} = \frac{\text{Distance}}{\text{Time}}$$

$$\therefore \text{ V} = \frac{\text{Wave length}}{\text{Time}}$$

$$= \text{Wave length} \times \frac{1}{\text{T}}, \text{ and } \frac{1}{\text{T}} = \text{N}$$

$\therefore$ Velocity = Wave length $\times$ vibration number on frequency.

With these elementary facts in our mind, let us direct our attention to the subject of wave motion found in different media, and as we are an Institute of Marine Engineers it is natural that waves in water should claim our first attention.

To produce a wave motion the association of matter and energy is necessary. These two fundamental agencies of nature, which manifest themselves in different forms, are increatible and indestructible (under human agencies). The definitions and laws associated with them are outside the sphere of this article, but it is not amiss here to state that, as far as the scientist is aware, matter and energy are inseparable. Matter is the vehicle of energy, it is the medium through which energy manifests itself, and wave motion is one of the means of transmitting energy by means of matter.

A true wave can only exist in a medium possessing elasticity and inertia. An elastic substance is said to be one which resists any strain set up in it, and when the force producing that strain is removed, it returns to its original condition. Again, due to inertia, the particles in motion overshoot the mark, as it were, and thus acquire potential energy which enables them to continue the cycle of operations. Thus it is seen every wave motion is made up of energy of strain and energy of motion, that is, potential and kinetic energy.

In the case of sea waves, the impact of the air currents on the surface of the water cause an elevation (the exact action has not yet been ascertained). The particle is thus lifted up, acquires potential energy, which is next converted into kinetic energy as the mass falls. The motion of the particles in deep sea waves is, however, circular. It first rises up, next moves forward, then falls, and lastly drags back. It is this dragging back which constitutes one of the dangers of sea bathing.

The velocity of water waves is dependent on their frequency, and herein lies one of the differences between waves in water and waves in other fluids, where waves of all lengths, etc., travel at the same velocity.

Note.—The deep sea wave, $V = 2\frac{1}{2}$ wave length.

Storm waves are merely surface disturbances, and do not extend to more than a few hundred feet below the surface.

Experimenting upon scientific lines is generally considered an expensive hobby, but there are many investigations which one interested in science can make at the cost of a little personal effort only, and the study of wave motion comes well within this classification. "Those who go down to the sea in ships" have abundant evidence that wave motion is a means

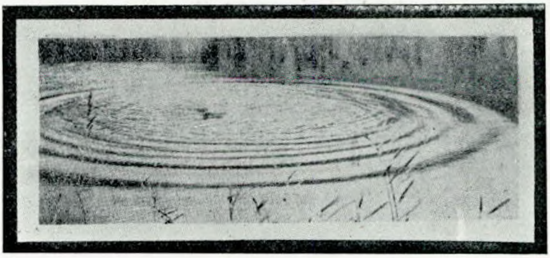


FIG. 2.

of energy transmission, especially when it is realized what an expenditure of energy is required to elevate and toss the modern leviathan of the ocean; but a much pleasanter mode of studying the subject is within reach of those of the profession who have taken up their abode on shore, and who indulge in the luxury of a seaside holiday. To these I would say, when occasion presents itself, throw a stone into some still pond or lake and watch the effect. First there is a splash, then one wave forms, which moves outwards unevenly in size, then multiplying in number, but getting feebler as they extend. A wave train has been set up, and it is interesting to note that the wave train velocity is actually less than the velocity of an individual wave. This can be distinctly noticed in a good wave train formation. (Fig. 2.)

Considerable information can be derived in this way, and it should be noted how the waves pass around obstacles, are reflected by large surfaces, etc., and in fact most of the phenomena which it is proposed to illustrate by slides can be so produced.

A study of canal wave formation is to be obtained by two large glass tubes similar to these here used, some two feet long and one inch diameter. By half filling the one and quarter filling the other, and placing them horizontally, models of

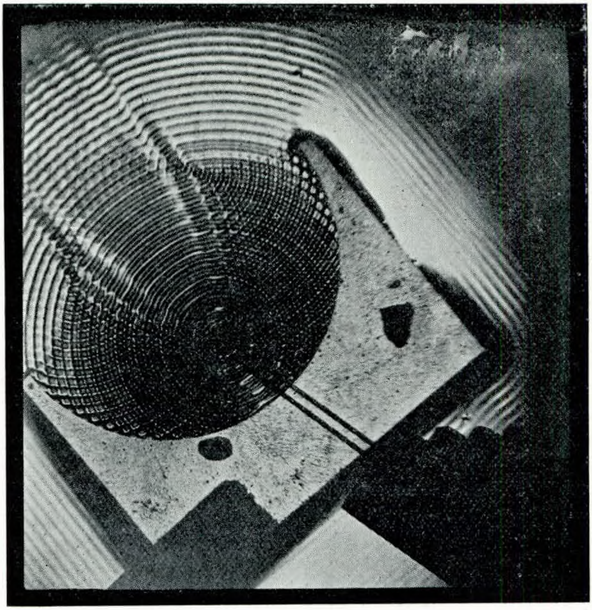


FIG. 3.

canals of different depths are obtained. When wave motion is produced in both simultaneously, it will be noticed that their speed is not the same, the deeper one travelling faster, also that the waves are oscillating in nature. From this it is obvious that with water waves the speed of the waves is increased with an increase of depth.

Note also how the waves are reflected backwards and forwards, gradually becoming less and less until they die away, due to the energy being used up in friction, etc.

Water waves can be shown to obey the same laws as light, which is also a form of wave motion, and in this direction a few experiments carried out with a saucer of mercury and various reflecting bodies will well repay the time expended.

The following illustrations show ripples produced on either water or mercury.[1]

Fig. 3 illustrates the reflection of a wave train from a curved surface, the waves being set up close to the edge of the reflection. *Note* that two sets of waves are distinctly visible, one the original and one the reflected train of the original.

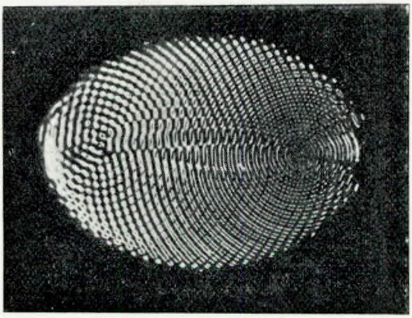


FIG. 4.

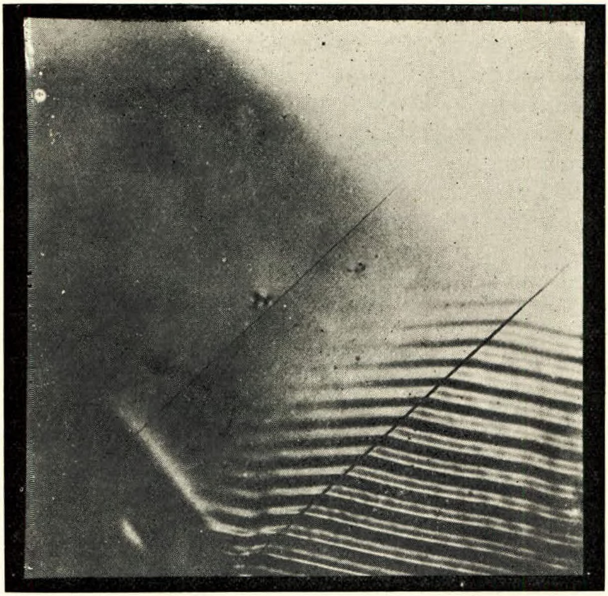
Fig. 4 is produced by fitting into the mercury bath an elliptical band. Waves are started at the focus, and after being reflected at the elliptical bounding, they converge to the other focus.

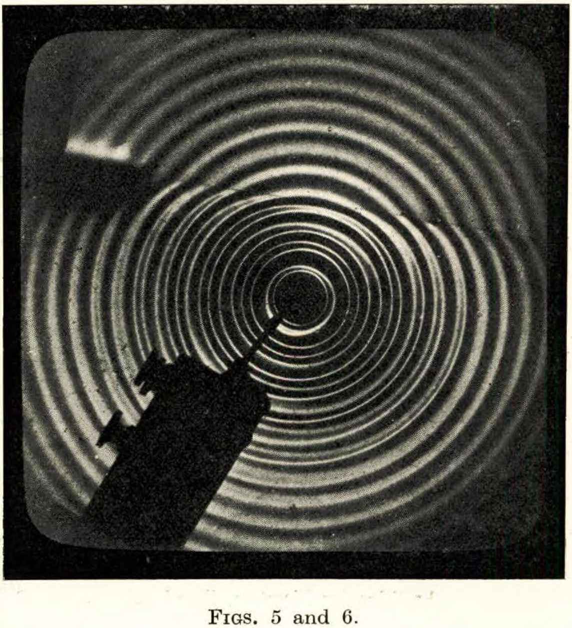
Figs. 5 and 6 illustrate refraction of a wave train due to the increase of depth, increasing the velocity. This is obtained by inserting in the trough a flat plate to reduce the depth.

By far the most important fact to note as regards the evidence of wave motion is the phenomena of interference.

Suppose that two separate and distinct wave trains of equal velocity start from two separate points, A and B, and that at point P the crest of A wave meets the hollow of B wave. Obviously one will neutralize the other and there will be no wave effect. So, also, at any other parts P, when the distance of any part P from A and B is constant, wave interference will be obtained. (Fig. 7.)

[1] Slides by Newton, London.





FIGS. 5 and 6.

The distance AP and BP in this case is obviously an odd number of half wave lengths. If, however, two crests meet at P, then the combined crests will increase the wave height, and vice versa in the case of two hollows meeting.

Figs. 8 and 9 illustrate various forms of wave interference, and it must be borne in mind that an indication of wave interference is the strongest evidence of the existence of wave motion in a medium.

So far as we have gone our attention has been directed to surface waves. It is now necessary to extend our investigations to longitudinal wave motion, such as is produced in gases. A further study of the mechanical model will throw some

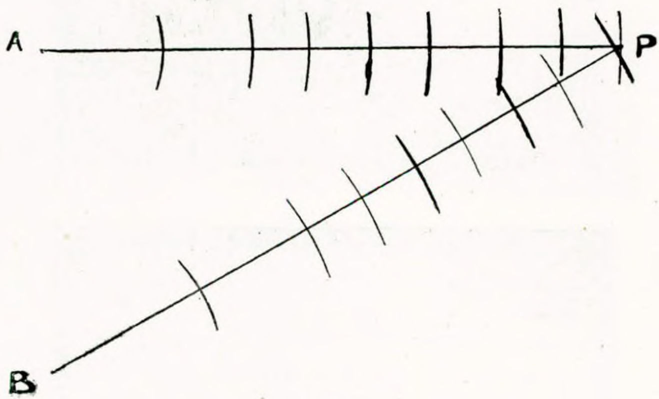
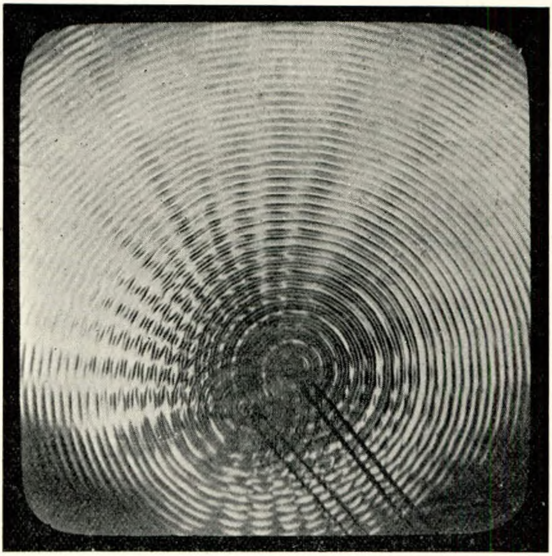


FIG. 7.

valuable light upon this subject. Notice the spiral, when struck a sharp blow, is first compressed, then elongated. When sound is produced a wave motion of this type is set up in the atmosphere. For instance, by striking this gong, the metal surface is set in vibration; this vibration compresses a spherical layer of the air, which quickly expands again, thus compressing the next outer air layer, which in its turn operates in a similar manner outwards, and so on. In this way a spherical longitudinal wave is produced, the particles oscillating backwards and forwards in alternate compression and rarefaction and proceeding radially from a centre outwards, transmitting sound by its motion to the human ear, like tones being



FIGS. 8 and 9.

governed by the wave length, intensity of sound by the amplitude, and the quality of tone by the wave form.

The speed of sound in air is approximately 1087 f.p.s. at 32° F., and at this rate it would take a sound wave sixteen hours to pass round from England to New Zealand. At all other temperatures the velocity of sound is governed by the formula :

$$1096\sqrt{\frac{273 + t^\circ}{273}} \text{ (t being degrees centigrade)} = V.$$

Wind currents and air densities greatly influence the velocity of sound, and many peculiar and interesting phenomena are to be experienced which have their origin in peculiar combinations in this direction. The velocity of sound in any other medium varies as $\sqrt{\frac{\text{elasticity}}{\text{density}}}$. The average velocity of sound in a few gases is usually quoted as follows :—

Hydrogen,	4163 f.p.s.
Air,	1090 f.p.s.
CO_2,	850 f.p.s.

Wave motion in gases, "including air," can be reflected, refracted, and in fact made to obey the laws associated with light and heat.

Reflection is well illustrated by means of two cardboard tubes some 3 feet long and 3 ins. diameter, placed at right angles to each other.

Sounds passing along one tube can be reflected by means of a solid surface, suitably placed along the other tube, as indicated by the deflection of the sensitive flame placed at the extreme end of the second tube. Celluloid lenses and prisms charged with CO_2 gas can also be used to produce startling optical effects with sound waves.

Heat, in a similar manner, can be reflected, and in this case two bright tin tubes take the place of the cardboard ones, and an electrical indicator in the form of a thermo-pile used to detect the reflected heat waves.

One of the most important discoveries in connexion with wave effects was that of Dr. Thomas Young, who conducted some very conclusive experiments in connexion with wave interference of light. He produced two pencils of one colour light emanating from the same source, by means of holes punched in an opaque board. These two rays were allowed to fall upon a screen. It was found that when one beam only illuminated the screen a clear disc of coloured light was the result, but when both apertures were open, then dark bands appeared on the screen, due to wave interference, i.e., "the crest of one light wave was neutralizing the hollow of another light wave." This discovery led Young to conclude that there must be a medium in which this wave motion operates; and thus the evidence of some hitherto unknown medium is apparent. This medium, which permeates all substances and all space, Young called the "luminiferous æther," and the great similarity between this æther and the "electro-magnetic medium" of Maxwell leads to the conclusion that they are one and the same, consequently heat, light and electricity are merely different forms of wave motion in this medium.

So far the only known way of setting up artificial vibration in the æther is by means of an electrical discharge of a condenser. It is therefore advisable to consider the condition of such a discharge. I do not propose to attempt a definition of an electrical current. Fleming gives it as "a physical state or condition which can only exist in a closed circuit." Now this circuit may be either a conductor in the form of a wire, or the like, or a non-conductor.

There are two sorts of electrical currents, the direct and alternating. The alternating is that with which we are most concerned at the moment. It is also defined by Fleming as "one which periodically changes its direction in its circuit." The time in fractions of a second which elapses between the commencement of a current in one direction and the beginning again in the same direction is called a complete period, and the number of complete periods in a unit of time is termed the frequency; and thus it is obvious we have a decided analogy between this phenomena and wave motion as previously explained, and with which we marine engineers are so familiar, —at least, in some of its phases.

The presence of an alternating current can be detected, as you all are aware, by Faraday's experiment of induction, the principle upon which the transformer is based. The force producing motion in a current is termed the electro-motive force, "E.M.F." and it can be produced in many ways. It is the E.M.F. which creates a flow of electricity in a conductor. It is the E.M.F. which creates an electrical strain in a di-electric or non-conductor. Professor Fleming's analogy of the air pump explains this admirably, and is one which should specially appeal to marine engineers. He says: "Supposing an air pump with a pipe at the bottom, fitted with a cork. When the tap is open, and force is applied to the piston, there is a continuous flow of air through the pipe.

Here the pressure corresponds to the E.M.F., and the air flow to the direct current in electricity. Now close the cock and depress the piston. At once the elastic resistance of the air is experienced, the piston can be depressed a certain distance, and then there is created in the air a form of strain. Now remove the pressure, and the elastic force drives the piston up. The piston, due to inertia, overshoots the mark, returns back and comes to rest after a series of oscillations."

To illustrate this electrically, let us perform an experiment by charging an electrical condenser, "an ordinary Leyden jar." A vacuum tube is inserted in series with the jar. This tube glows when an electrical current is passing, and so acts as an indicator.

Note, when charging begins, the tube lights up, but as charging continues the tube's glow gradually dies down as the jar becomes charged up. In the glass an electrical strain has been produced in an analogous manner to that produced in the air of the pump. Now discharge the jar by means of the usual discharging tongs; this strain is released, and is accompanied by an electrical spark—which is in reality a series of electrical oscillations somewhat similar to those of the piston of the air pump. This spark has been photographed by means of a rotating mirror and is clearly of an oscillating nature.

As this discharge is a very important factor in the subject of this paper, it will be advisable to investigate the nature of such a discharge more closely, and therefore I purpose demonstrating by means of an experiment—an alternating high frequency electrical discharge.

It is a well-known fact, and one which we have already referred to, that an alternating current in one circuit can produce an alternating current in another circuit.

I have here two closed circuits (fig. 10). One is fitted with a glow lamp, the other is connected up to a battery of Leyden jars charged from an induction coil. Now, when electrical oscillations are produced in the primary circuit, due to the discharge of the electrical condensers, or Leyden jars, and the secondary circuit is brought in close proximity to it, "parallel" oscillations will be produced in the secondary circuit of sufficient strength to light up the lamp. This not only proves the discharge from a Leyden jar to be of an oscillatory nature, but it is an illustration of what is called forced oscillations. To obtain the best effect from all such conditions it is necessary that the two circuits should be tuned one to the other. The oscillation constant which is expressed by the square root of the condenser capacity and the inductance of the circuit must be equal for the best results to be obtained. This is merely applying to electricity the well-known dynamical truth, that any system capable of being set in vibration can have large oscillations created in it by experiencing small

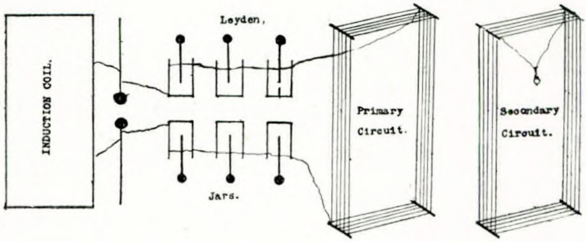


FIG. 10.

impulses at intervals equal to its own free period of vibration. Say, that in an electrical system an E.M.F. causes an increase of potential energy, and if the system is then left to itself it will execute a series of oscillations, the time period of which is expressed by the formula (fig. 10):

$$T = 2\pi\sqrt{CL}$$

when C = the capacity of the condensers, and L = the inductance of the circuit. In the system before us the inductions are obviously equal, and when the capacity of the circuit is brought nearer equal by inserting in the secondary circuit two Leyden jars, it will be noticed that the inductance effort is greatly increased, because the capacity and inductance of both circuits is nearer equal. This will, I trust, somewhat clear up the sometimes mystery of tuning a circuit, etc. When an ordinary Leyden jar is discharged, due to the electrical strain in the jar, a series of electrical oscillations is set up, it being estimated that some thirty oscillations take place in about $\frac{1}{100,000}$ part of a second.

We are now in the realm of what is termed "High Frequency electrical currents." This, is, however, merely an alternating current with a frequency reckoned in thousands. Again, an electrical oscillation has a very high frequency, which, according to reliable authorities, can be taken as one million. It should be noted, however, that there is no absolute demarcation between an alternating, high frequency, and oscillating current. The term is purely a relative one.

As before stated, no other means of executing an æther wave has been discovered other than by an electrical oscillation. It is advisable to glance briefly at the effects produced by a pair of electrified rods and balls (fig. 11) termed a spark gap, when connected to the secondary terminals of an induction coil, and brought to a potential just sufficient not to spark across. These rods have a + and − charge, and, consequently, an electrical strain is produced in the surrounding medium ; such a condition is similar to that associated with a charged Leyden jar. Consequently, when the spark passes between the balls, it is of an oscillating nature. This discharge creates a change in the electro-magnetic medium or æther around the rods, giving it a kick, as it were, which kick is transmitted through the medium at a certain definite velocity. Our spiral wave motion model gives a very good illustration of such waves produced in the electro-magnetic medium. It will be noticed that the discharge balls really play the part of an electrical condenser. In fact, any system of metal surfaces or plates separated by an insulator or di-electric is an electrical condenser. An electrical condenser may be constructed by coating a sheet of glass with tinfoil on either side. (Fig. 11.)

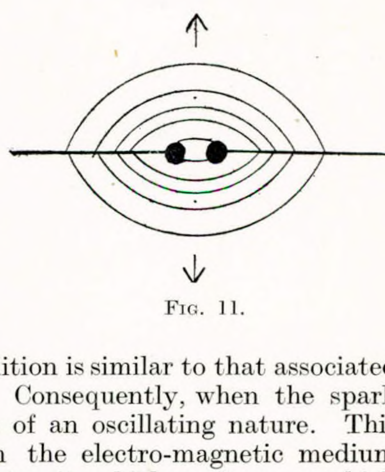


FIG. 11.

Hertz (Fig. 12) oscillators are really condensers where the air takes the place of the glass insulating plates, and with which apparatus he was enabled to perform such epoch-making experiments.

The radiator or oscillator as used by Hertz consisted of two metal plates filled with short wires and discharging knobs. The plates were placed in line with one another, the knobs about $\frac{1}{4}$ in. to $\frac{3}{8}$ in. apart. The knobs are then connected to the secondary winding of an induction coil. Now, when the E.M.F. accumulates, a strain is set up in the di-electric medium, and when the spark passes at the balls, this electric strain is suddenly released, and this suddenly released electrical strain sets up what is termed an electrical wave in the electro-magnetic medium, which wave motion,

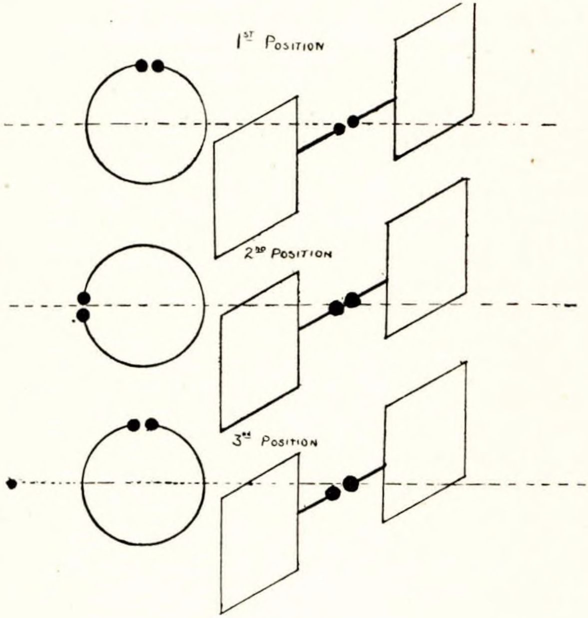


FIG. 12.

travelling outward from its centre of origin, conveys to distant places an alternating electrical strain which has originally been produced in the medium by the rapid oscillating electrical discharge. It will be noticed that the Hertz oscillator, with its two plates and surrounding air insulation, is a form of electrical condenser, and the discharge creates in the space around a magnetic flux, the direction of which is everywhere normal to the electrical displacement.

This electro-magnetic energy is converted into electro-kinetic energy, and when the induction coil is kept in operation, trains of electric waves are sent off into space. To produce a good electrical oscillation; the spark balls must be clean and highly polished, and no ultra-violet rays must fall upon them ; and, again, the balls must be a certain distance apart to induce an oscillatory discharge. This latter is determined best by trial.

The fact that these æther waves exist can only be conclusively proved by devising some means of detecting them. Hertz used a form of resonator, which consisted of a ring of wire, the two ends of which were fitted with highly-polished brass balls, the space between the balls being adjusted by a micro - meter screw. When this resonator is placed in position parallel with the plates of the radiator and in a line with them, and the radiator set in operation, small sparks occur between the balls of the resonator, but when the resonator is turned round, bringing it in such a position with the oscillator that its spark axis is perpendicular, no spark passes. By attaching a small vacuum tube charged with CO_2 gas across the balls of the resonator, the effect can be better seen by an audience. (The experiment was performed in detail.) Again, the resonator can be placed in a horizontal position, with its axis in the same line as the oscillator axis ; then when the resonator spark balls are in close proximity to the oscillator discharge, the tube again lights up ; but as the resonator is rotated, the illumination of the tube dies away, until, when the spark balls of the resonator is at its furthest position from the oscillator, no effect whatsoever is observed. (Fig. 12 illustrates the experiment.)

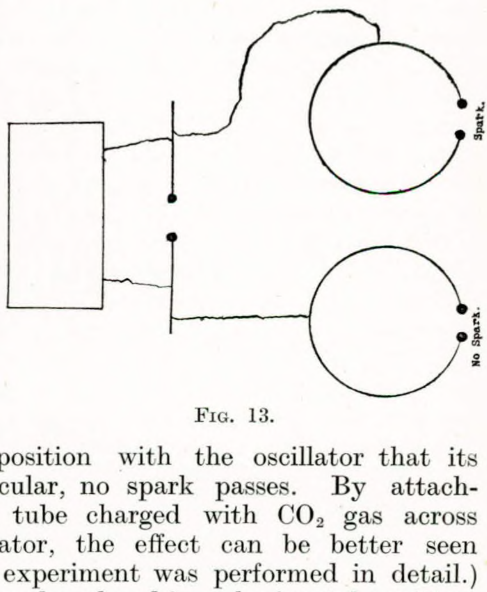


FIG. 13.

To obtain a clear idea of what is taking place, connect the resonations to one terminal of the induction coil—first, at a point symmetrical with the spark balls, and, secondly, at a point of unequal distance to the spark balls. In the first instance, no spark passes the resonator balls. This is due to the inductance of the resonator circuit. (Fig. 13.)

In the second instance, however, vigorous sparking takes place, due to the unequal inductance of the current, giving rise to a difference of potential between the balls.

In a similar manner, when the resonator is not connected to the spark gap, as in Hertz experiments, if the spark gap of the resonator is held parallel with the spark gap of the radiator, a difference of potential is produced which is of an alternating nature, due to the electro-magnetic medium displacement, and when the difference of potential reaches a certain amplitude, the air insulation breaks down, which is indicated by the small spark passing at the balls.

In the case of the resonator being held with its spark gap at right angles to that of the radiator, the electric force transmitted by the radiator is not in a direction to cause a difference of potential between the balls of the radiator, consequently no spark passes.

The functions of the resonator can be now briefly stated as follows. It is really an electrical circuit possessing capacity and inductance, the spark balls constituting a type of electrical condenser. It, consequently, has a natural free period of oscillation or electrical vibration, and, consequently, when an electrical strain is produced in the insulating medium (the air) and assuming that it synchronizes with the natural free period, then the amplitude of the displacement oscillation is increased, and ultimately the air insulation breaks down between the balls, and a spark passes.

The name of Hertz will always be associated with æther waves. His great achievement was the formation of stationary electric waves by means of a radiator and resonator similar to that described, together with a reflector consisting of a large metal sheet, which was set up parallel with the radiator plates.

The resonator was held with its plane parallel to the metal sheet and its spark gap parallel to that of the radiator. When the resonator was held near the reflector, no spark passed, but when moved away, sparks appeared, a point of maximum brilliancy also being observed. Again, when the resonator was placed still further away from the reflector, the sparks died away, which indicated that in the space bounded by the radiator and reflector a periodicity of electrical force was set up, and by means of the resonator the nodes and antinodes can be traced out.

These electrical waves can be reflected, refracted, polarised, and the phenomena of wave interference produced by the aid of paraffin lenses and prisms and by encasing the radiator in a suitable metal directing box. Time, however, will not permit dwelling upon this very interesting section of the subject.

Stationary electrical waves in wires can also be produced by means of the apparatus before you. (Fig. 14.)

A long coil of insulated wire is connected up to the induction

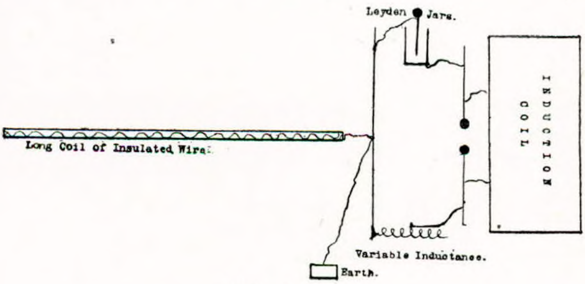
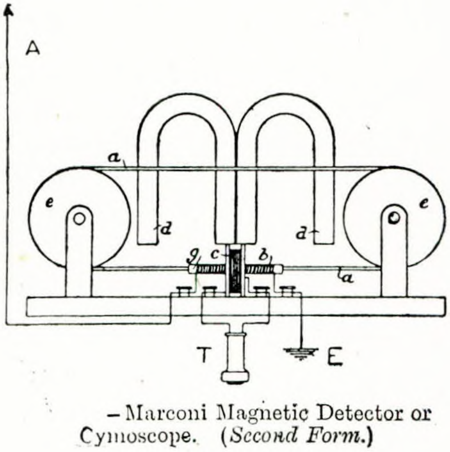


FIG. 14.

coil, together with a capacity and inductance, as shown in Fig. 14, and, by a little adjustment, the nodes and antinodes of potential can be traced out by the aid of a vacuum tube of the Nion type. The tube is held close to the wire in which the waves are produced, and lights up and dies down in accordance with its position, the non-luminous points being the nodes of potential of the wave. To obtain a stationary wave in a wire a high frequency E.M.F. is necessary, and it can be accomplished by connecting the wire in which it is proposed to create the wave effect directly to some point in an oscillatory circuit, say to a Leyden jar, and then, when the jar is discharged, oscillations are consequently set up in the wire, which results in a wave of potential in the wire, which wave, running along the conductor with the velocity of light, is reflected back from the open end, just as the wave sent along a fixed rope is reflected back to the person causing the motion at the free end.

Marconi practically took the Hertz oscillator and buried one part in the ground, thus forming his aerial. He then connected the insulated aerial to the spark ball of an induction coil, the other spark ball of the coil being connected to the earth plate. Thus a sort of condenser is formed by the insulated aerial, the earth and the surrounding air. Consequently, when the aerial is charged with electricity, lines of electric strain are, as it were, set up from it to the earth in all directions. Now, when a discharge takes place, electric waves are created, as in the case of an ordinary Hertz oscillator.



– Marconi Magnetic Detector or Cymoscope. (*Second Form.*)

FIG. 15.

(From Fleming's *Wireless Telegraphy.*)

By this device Marconi brought signalling by electric waves within the sphere of the practical.

As it is merely my intention to broadly indicate the chief facts associated with wave motion in general and waves set up in the electro-magnetic medium in particular, the detailed consideration of wireless telegraphy does not come within the scope of this article. For information in this direction reference can be made to a previous paper read before this Institute by Mr. McLaren, but a broad survey of the various practical types of electric wave detectors is necessary to complete the scheme of this paper.

First and foremost as an electro-magnetic wave detector stands the human eye, which, as light has been proved to be a form of short electric wave motion, can be termed Nature's electric wave detector.

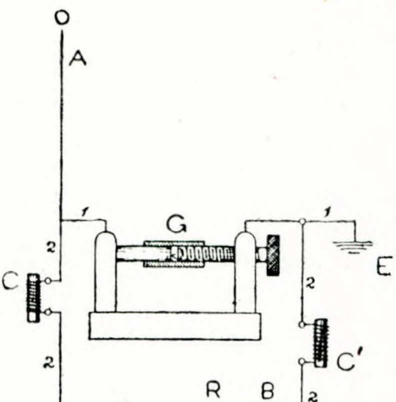
The Hertz resonator is the historic form of electric wave detector; but as we have dwelt a considerable time on it, it is unnecessary to enlarge further.

Next comes the "coherer," or contact detector, where operation depends upon the fact that when finely powdered metal or other conducting material, when finely packed, is a non-conductor under the influence of a small E.M.F., but becomes a conductor under the influence of a high E.M.F. It is difficult to say when the first idea of the coherer originated, for associated with it are many eminent names, including Bramley, Lodge, and others. An inspection of the coherer before you will explain its construction. The modern coherer is exhausted of air to prevent oxidation taking place only. The magnetic detector is constructed under many forms. The broad principles can, however, be obtained from considering the Marconi magnetic detector. It consists of two fixed magnets and a flexible iron band passing on two pulleys and under influence of the magnets. (Fig. 15.)

The iron band passes through an insulated glass tube, which tube is wound with a coil of insulated copper wire. Another coil of wire is wound on a bobbin over this, the ends of which are connected to the telephone receiver. Now, when the iron band rotates, the magnetic retentivity of the iron causes the magnetic parts of the band to be a little away from the poles of the magnets. Then when an electric oscillation passes through the coil of wire, one end of which it will be observed is connected to the aerial and the other to earth, the hysteresis of the iron is annulled and the magnetic part shifts, as it were, back directly opposite the magnetic poles. This is practically equivalent to moving a magnet through the coil of a telephone circuit, and, consequently, an induced current is generated which is inducted in the usual way by the telephone receiver.

Another form of detector depends upon an electrolytic action, and among these the De Forest system can be cited, which consists of a tube filled with two metal plugs, the space between containing a mixture of some such substance as glycerine and water, together with a proportion of metal filings. Other mixtures are also used. The metal filings act as electrodes. A local current is passed through the tube in series with a telephone receiver, etc. (Fig. 16.)

The electrodes are connected to the aerial and earth respectively. When an electrical oscillation passes through the cell from the aerial it breaks up the chain of metal particles and results in an interruption in the local current and a consequent signal at the telephone.



De Forest Electrolytic Detector.

FIG. 16.

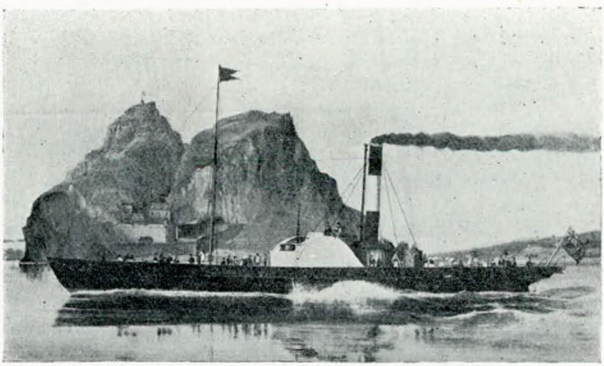
(From *Wireless Telegraphy* by Fleming.)

Vacuum tubes, modified in certain directions, have also been used as wave detectors, and under this heading can be classed Fleming's electric valve.

Again, the peculiar property various crystals have of rectifying an alternating current when the surfaces of the substance in contact with the crystal is very small, is largely used as a wave detector. Certain crystals have this peculiar property very marked, for instance, carborundum (a silicate of carbon) is so sensitive that it will operate even without a local electric current.

The extension of electrical apparatus on board ship has of late years gone beyond the range of a ship's dynamo.

It is the knowledge of this fact which has induced the author to pen this paper, scanning the various phases of wave motion which now comes within the realm of that miniature world, a modern steamship; and it is hoped that marine engineers, when they realize they are dealing with merely another phase of a familiar subject, will attack, and master, the broad principles of wireless telegraphy, and be as capable of effecting repairs and detecting faults as they have been in the past when other innovations, such as refrigeration, the dynamo, oil fuel and oil engines, have been forced into their already very full but ever attractive care.



PADDLE STEAMER "LOCH LOMOND."

In view of the article on the *Comet* Centenary Celebrations on the Clyde and the Introduction of Steam Navigation contained in the last issue of the Transactions, the above illustration will be of interest. It is reproduced from a painting of the paddle steamer *Loch Lomond*, the first steamer built by the firm of Messrs. William Denny & Brothers of Dumbarton. The vessel was built in the year 1845.

"Titanic" Engineering Staff Memorial.

The Fund now amounts—October 5th—to £2,150. During the past month the subscriptions received amounted to £300, including the following sums of £10 and over :—

	£	s.	d.
Messrs. Denny & Co. (employees £25, and contributed by the firm £25)	50	0	0
Collected by P. D. Daly, 416 Ayacucho, Lima, Peru	30	0	0
Collected by J B. Linn, Dock Ironworks, Bombay	10	0	0
Collected by R. Watson, Burmah Oil Co., Ltd., Rangoon	13	8	6
Collected by A. Augustus Ragg, Engineer Surveyor, Fiji Marine Board	12	5	0
Collected by Matthew Turnbull, 8, Spinkfield Road, Birkby, Huddersfield	11	11	0
Collected by John Young, The Asiatic Petroleum Co., Singapore	10	10	0

The full list of steamers from which subscriptions have been received to date, is appended hereto.

Afghanistan
Anglian
Arabia
Arawa
Ascot
Baron Garioch
Barrow
Beacon Grange
Beckenham
Bellona
Beltana
Berbera
Beryl
Blackheath
Borderer
Cadillac
Cairngorm
Caledonia
Cambria
Camio
Canadian Government Steamers :
- Aberdeen
- Curlew
- Druid
- Earl Grey
- Governor Cobb
- Lansdowne
- Lady Laurier
- Montcalm
- Stanley

Caradoc
Carpentaria
Castor
Centipede
Cervona
Ceylon
Champion
Chanda
Chiswick
China
Chyebassa

City of Corinth
City of Edinburgh
City of Poona
City of Vienna
Cobra
Colaba
Colonia
Commonwealth
Cornelian
Crane
Culna
Delaware
Demosthenes
Devon
Devona
Durham
Eden Hall
Emerald
Envoy
Essex
Estrellano
Frankmere
Fremona
Geelong
G.E.R. Steamers
Gibel Dersa
Gibel Kebre
Gibel Tavik
Gibel Zedid
Girasol
Glenlogan
Glenroy
Golconda
Guelph
H.M.S. Amethyst
H.M.S. Black Prince
H.M.S. Canopus
H.M.S. Dartmouth
H.M.S. Derwent
H.M.S. Electra
H.M.S. Fervent
H.M.S. Gloucester
H.M.S. Implacable
H.M.S. Lightning
H.M.S. Kestrel
H.M.S. Majestic
H.M.S. Ness
H.M.S. Rattlesnake
H.M.S. Recruit
H.M.S. Ringdove
H.M.S. Zebra
H.M.T.B.D. Brazen
H.M.T.B.D. Vulture
H.M.T.B.D. Zephyr
H.M.T.B.D. Cynthia
H.M.T.B.D. Porcupine
H.M.T.B.D. Coquette
H.M.T. Boats Nos. 071, 079, 3, 6, 7, 8, 9, 10, 11, 12, 17, 18, 19, 20, 23, 30, 112, 113, 114, 115
Highland Brae
Highland Pride
Highland Warrior
Himalaya
Hindu
Henley
Horlington
Hurona
Hurunui
Hydra
Ilford
Inanda
India
Ingeli
Inkosi
Intaba
Insizwa
Iona
Iroquois
Jacona
Jaffa
Jelunga
Kadett
Kaikoura
Kaipara
Karamea
Karonga
Katuna
Kia Ora
Kioto
Kistna
Kumara
Kyanite
Lady McCallum
Lake Erie
Lake Michigan
Lunka
Mackinaw
Magnet
Makarini
Maloja
Malta
Mamari
Manitou
Mantua
Marmora
Matatua
Matiana
Media
Milleped
Miltiades
Milwaukee
Mimiro
Min
Minneapolis
Minnehaha
Minnewaska
Moldavia
Mombassa
Monmouth
Montcalm
Montezuma

Montfort
Montreal
Montrose
Mooltan
Morayshire
Morion
Mount Royal
Mount Temple
Muttra
Namur
Nephrite
Nile
Nore
Norfolk
Nubia
Nyanza
Nyasaland
Omrah
Opawa
Ophir
Orama
Orontes
Orvieto
Osterley
Otaki
Otranto
Ottawa
Otway
Palawan
Palermo
Palma
Patrol
Pera
Persia
Perthshire
Peshawur
Plasma
Plassy
Ploussa
Poona
Prase
Prince Rupert
Pyrope
Rakaia
Rangatira
Recorder
Remuera
Rio Squassa
Rotorua
Royal Edward
Ruby
Sagenite
Sard
Sardinia
Seldanha
Sentinel
Servian
Shenandoah
Shropshire
Sicilian
Simla
Socotra
Somali
Soudan
Star of Scotland
Sumatra
Sunda
Tainui
Themistocles
Tongariro
Trocas
Twickenham
Ula
Waimana
Waimate
Waipara
Waiwera
Wallaroo
Walter Dammayer
Warwickshire
Willesden
Wiltshire
Woodford
Zaida

The following paragraph is copied by permission from *The Marine Engineer and Naval Architect* of September, and when it is further observed that, at the September election of orphan children for the Merchant Seamen's Orphanage, eight of the candidates were children of Marine Engineers, it is manifest that strong efforts should be put forth to raise a large Fund for the purpose of dealing specially with such cases. It has been suggested that the engineers of every steamer might gladly contribute every year. A small amount from each would aggregate to a substantial sum and ultimately admit of carrying into effect a noble and useful undertaking which would be identified with the Memorial. The paragraph referred to is as follows :—

A Home and Schooling for the Children of Marine Engineers. —An esteemed correspondent in the Far East has advocated the founding or establishing of a home and arrangements for the education of children of marine engineers whose duties demand their location in lands where children cannot receive that training and education which their parents desire them to have. Many children are sent home to boarding houses or schools, and in some cases the fathers have but little knowledge of those to whom the care of the children is entrusted, dependent as they are upon information from circulars or correspondence. One case is cited where one child was not by any means done justice to in regard to education, in spite of high fees for board and schooling and of reports giving glowing results year by year. The father only discovered when his daughter joined him after some years how he had been deceived. The suggestion has occurred on account of the *Titanic* Engineering Staff Memorial, and the correspondence in connection with it. If a home for orphans of marine engineers could be founded as a memorial, it might be extended to serve as a boarding home with school arrangements for children of marine engineers serving in foreign waters or located in the marine engineering workshops ashore. The boarding home would form a paying part of the establishment, and yearly subscriptions from marine engineers all over the world would cover the payments for the orphans. The contributions to the Memorial are swelling the amount in the hands of the Institute of Marine Engineers, as pointed out by our correspondent, and in his enthusiasm he anticipates a large sum will be gathered, sufficient to form the nucleus of a fund to establish a home which will be looked upon with pride and satisfaction by all marine engineers throughout the world, a home to which they could with confidence send their own children in the consciousness that their education and training would be entrusted to true and faithful hands.

JAS. ADAMSON,
Hon. Secretary.