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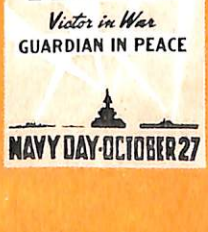
OCTOBER 1947

BUSHIPS Electron



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BUSHIPS Electron

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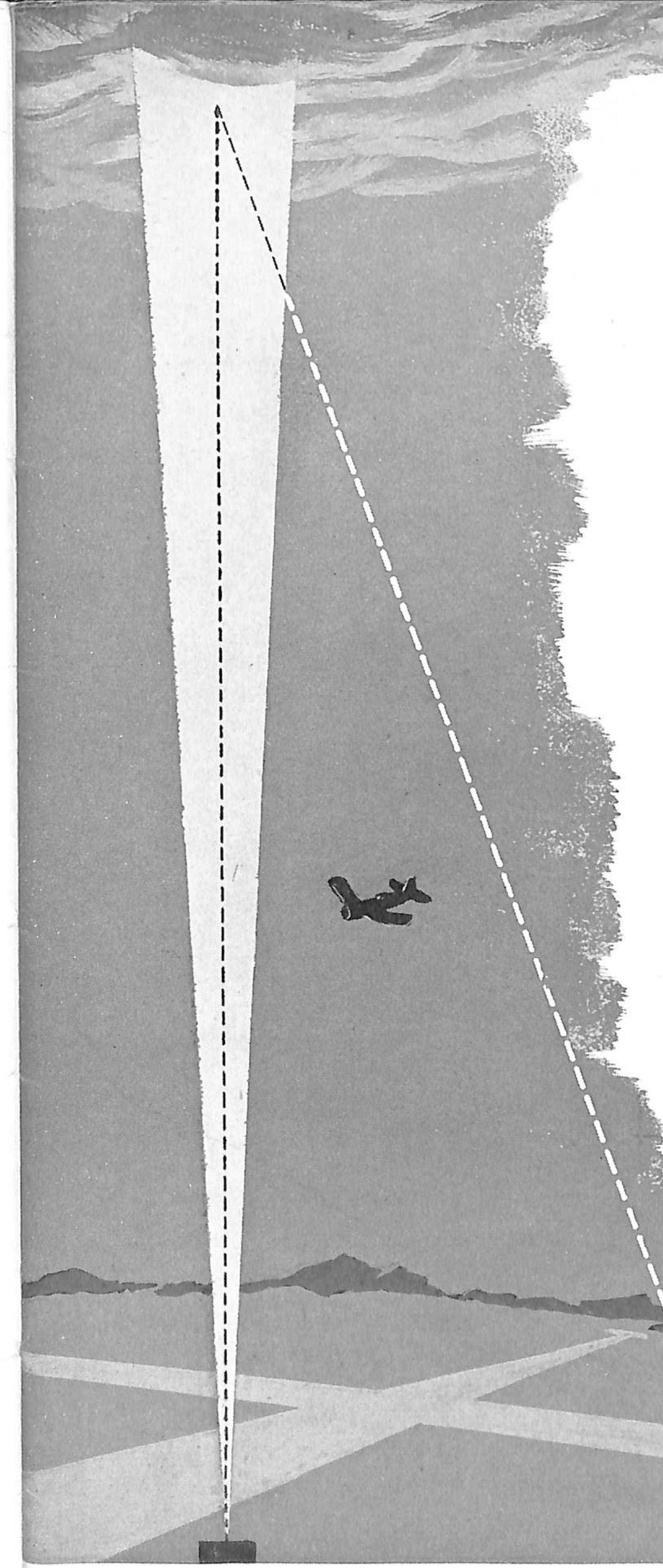


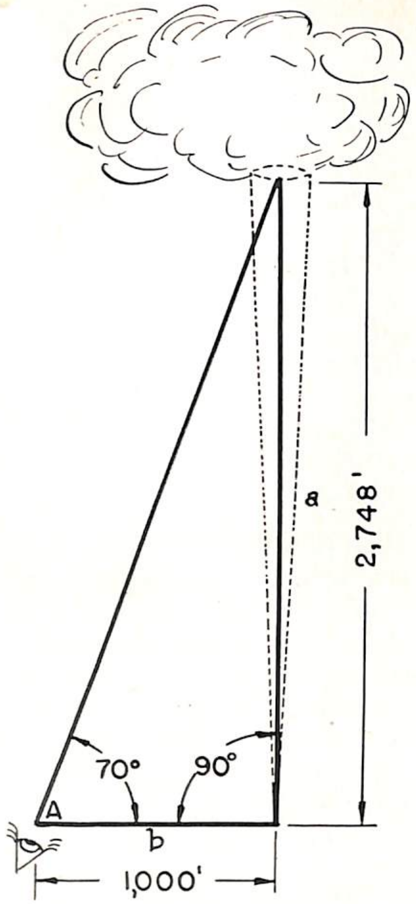
PHOTOELECTRIC CEILOMETER

■ The September issue of Electron carried a short item telling of the AN/GMQ-2 Photoelectric Ceilometer, and giving a few basic facts on the principles involved. The purpose of this article is to disclose some of the inner workings of the ceilometer. The concepts involved and the technical peculiarities of certain components make it interesting to study as well as useful.

The principle whereby a beam of light is projected skyward and the vertical angle measured from the the earth's surface to the spot of light made on the clouds is commonly used by meteorological services in determining the altitude of the cloud ceiling. An observer is stationed a known distance from the light source. Using an alidade he measures the vertical angle and converts it to altitude from a chart based on the fact that the altitude will always be the product of the known distance between observer and light source multiplied by the tangent of the angle determined. See figure 1. Thus, if the angle was found to be seventy degrees, and the distance between observer and light source is fixed at one thousand feet,

altitude $a = 1000 \tan 70 = 1000 \times 2.748 =$ 2,748 feet

Such a device can be used only at night, for the high intensity of daylight precludes the visual locating of the spot of light made by even the most



$a = b \tan A = 1{,}000' \times 2.748 = 2{,}748'$

FIGURE 1—*Knowing the distance between light source and observer, and vertical angle to spot in clouds, the altitude to the clouds may be determined.*

powerful searchlight. In reality a relatively low-power light source is employed. The accuracy obtained using this system depends largely on the judgment of the observer.

The AN/GMQ-2 Ceilometer is a device which employs a high-power light source rich in ultra-violet rays and automatically determines the vertical angle to the spot on the cloud, plotting the angle in a continuously-running graph. Observation of the graph at any time during daytime or night discloses the vertical angle from which can be determined the altitude to the cloud base. Observation of the graph of altitudes for the period of time preceding will disclose the rate at which the ceiling is falling or rising, which at times is of vital interest to pilots of planes approaching from some distance and planning to land.

The equipment can be divided into three major components: the projector, the detector, and the recorder. See figure 2.

ML-335/GMQ-2 PROJECTOR

The projector employs a G-E type B-H6 mercury-vapor arc lamp. As used in this equipment, this lamp provides 25,000,000 candle-power of light rich in ultra-violet rays and modulated at 120 cycles by the a-c applied. The B-H6 has an over-all length of about three inches including electrodes and a diameter of less than a quarter-inch. The small size and high intensity of the light source permits the generation of a powerful beam with only a parabolic reflector to gather, reflect and focus the light rays.

Parabolic reflectors of course are not new. For years they have been used in searchlights and hand flashlights, and more recently in microwave radar antennas. Since the principles behind such reflectors may not be known to some readers of this article, a few words about them are in order.

The parabolic reflector has the unique property of focusing light waves from a suitable and properly-located source into a bundle of parallel rays. This is shown in figure 3. Other radiations focused with parabolic reflectors are infra-red rays, ultra-violet rays, microwave radar waves and ultra-sonic sound.

This focusing property is provided by the shape of the reflector. It is so curved that no matter which rays from the source strike it, it will always present to those rays a reflecting surface set in at the correct angle to direct the rays outward, parallel to all the other rays. In that way the reflector is capable of providing a very narrow beam containing a large percentage of the total amount of light given off by the source.

Theoretically, with a perfect parabolic reflector and a perfect point source of light, a beam of light would be obtained which would be no larger at the far end than at the reflector. This condition is of course impossible to obtain, for it is not possible to generate a point source of light nor to grind a perfect reflector. In practice, however, a practical approximation is obtained, and a strong, narrow beam of light becomes a reality.

The light source in the ceilometer consists of a capillary quartz tube containing a small amount of mercury and filled with argon gas at a pressure of about one-fifteenth atmosphere. Sealed into each end is a tungsten wire which serves both as electrode and lead. When voltage is applied an initial current passes through the argon gas and vaporizes the mercury, bringing the pressure up to about 80 atmospheres. The current then flowing constitutes

an arc through the mercury vapor and thus provides an extremely bright light.

It has been determined by practical experiment that lamp life can be lengthened by reducing the number of times the lamp is turned on and off. The act of starting the arc within the lamp constitutes a small explosion due to the very sudden expansion of the mercury vapor with ionization. This is a characteristic of the lamp and cannot be changed. The effects, however, can be reduced by leaving the equipment on rather than securing it for short periods of time.

Since lamp failures are quite common and the average lamp life low, a lamp changer has been incorporated in the projector which removes the inoperative lamp and automatically substitutes a new lamp. The capacity of the automatic lamp changer is four lamps. Each new lamp is placed at the focal point of the parabolic reflector when its predecessor burns out. If a bad lamp is placed in position, the changer will again rotate to a new position and place the next lamp in proper location. Twenty seconds elapse between the time a new lamp is placed in position and the time that lamp will be rejected in favor of still another. This delay is to allow the newly-inserted lamp time to start. If the lamp fails to start in twenty seconds the changer mechanism substitutes a different lamp.

The lamp changer mechanism is located within the beam of reflected light from the reflector. Because it has a small cross-section area, however, and its plane being parallel to the light rays, the amount of light absorbed or diffused is not great.

The automatic lamp changer is more than a maintenance convenience. It is, in addition, a safety factor for the maintenance man, for it reduces the frequency of his possible exposures to electric shock and ultra-violet radiation. Both of these dangers are present in the ceilometer projector.

The transformer which furnishes high voltage for operation of the lamp is provided with a capacitance of 10 microfarads across an extension of the primary to raise the power factor to unity and to provide zero phase angle. Designed to give the highest practicable degree of stability in the operation of the lamp, the transformer provides 1225 volts initially to start the arc, and about 1000 volts after arc current starts flowing. The differential voltage of 225 volts is dropped across the windings of the transformer by the flow of 1.25 amperes in the secondary.

Dissipation of considerable energy in heat as well as light raises the lamp bulb to a high temperature. As a cooling agent to prevent the rise in temperature from exceeding a safe value, a blast of cool air is generated and directed on the lamp bulb without which the internal pressure of the lamp would build up to a high point and either explode the lamp or extinguish the arc. To prevent this an air compressor is started when control switches are closed, but before the high-intensity lamp is lighted. Power is applied to the lamp only after the air compressor builds up enough pressure to cool the lamp.

The air compressor provides a blast of air at 17 pounds pressure through two nozzles directed at the portions of the lamp near the electrodes. These parts are raised to the highest temperature with the lamp in operation. A surge tank is employed between the air compressor and the nozzles to smooth out surges in pressure and to provide a diminishing blast of air to the lamp after power is removed from both lamp and compressor.

ML-337/GMQ-2 DETECTOR

The preceding paragraphs explained the method by which a narrow beam of light of high intensity is modulated at 120 cycles per second and projected skyward. Before that beam can be utilized in determining the altitude to a cloud base the light reflected from the cloud must be detected and the vertical angle to the spot in the clouds measured.

It is the purpose of the ceilometer detector to collect some of the reflected light and focus it on a photoelectric cell and thus convert the light energy into electrical energy which can be amplified and carried to the recorder. Since the location of the spot of light in the clouds may vary as the clouds change altitude, the detector must be able first to locate the spot.

The photoelectric cell is mounted in a movable drum which may be directed upward and downward in a single plane through an angle of 90 degrees from the earth's surface. Associated with the p-e cell is an optical system designed to view the entire spot of reflected, modulated light on the cloud base, but no more than that spot. See figure 4. The optical system, consisting of a single lens, suitable aperture and a baffle, allows the reflected, modulated light to reach the p-e cell but excludes as much daylight or other incidental light in the sky as possible. Such extraneous light is a source of great difficulty as explained in the following paragraphs.

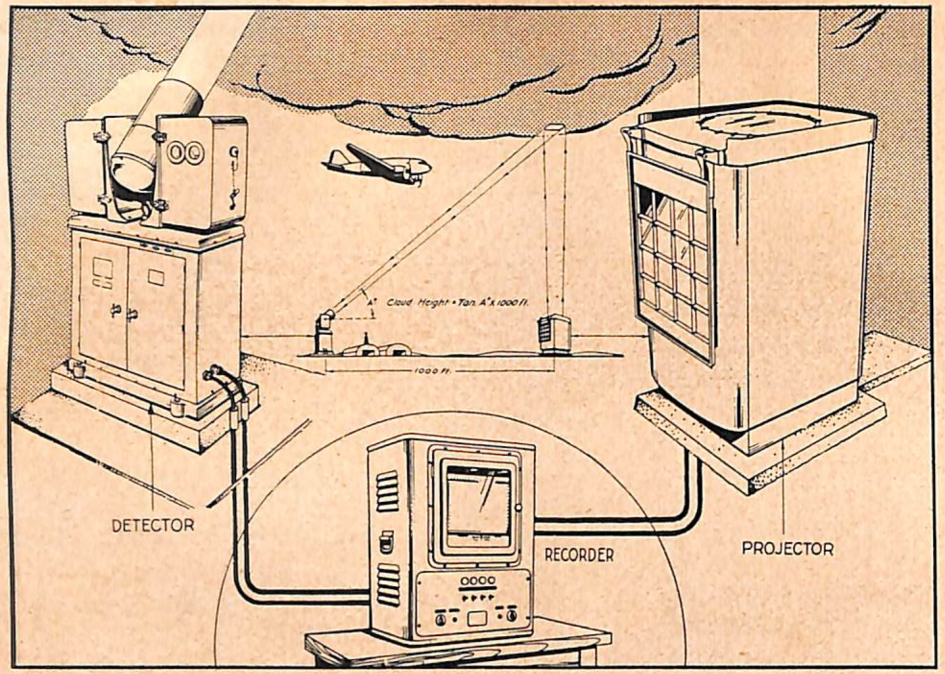


FIGURE 2—*Ceilometer equipment AN/GMQ-2. Schematic layout.*

The drum is moved through its arc by a synchronous motor. Through a gear box and a pulley drive, the drum moves through 90° of arc in six minutes, returning then to its horizontal position as the direction of rotation of the motor is reversed. Geared to the drum, but located in another compartment of the detector, is a selsyn generator which transmits the vertical angle of the drum to the recorder. Through this system, the vertical angle between the earth's surface and the spot in the clouds is measured and transmitted to the recorder.

Detection of the modulation component of the reflected light is accomplished in spite of serious difficulties brought about by the character of daylight and the high degree of amplification necessary for the relatively weak reflected light to be made usable. Shot noise is very pronounced. It is caused by random emission of photoelectrons in the p-e cell when the cell is subjected to light intensities comparable to that of daylight. This emission generates an electrical voltage of random character which may exceed by many times the magnitude of the modulation component of the reflected light from the ceilometer projector and obliterate the desired signal. Part of this noise is filtered by the amplifier, but although the amplifier will pass only those frequencies lying between 85 and 165 cycles, still enough random noise will pass to be of grave concern and to make necessary the use of another device for discriminating against such noise.

Another source of noise, one which is present in any high-gain amplifier, is that of thermal agitation which is introduced as the result of current flowing through a resistance. In the ceilometer this effect is reduced to a negligible factor in the design of the preamplifier. Specifically, a high voltage and a high value of series resistance are employed in the p-e cell circuit.

The amplifier provides a voltage gain of two million at audio frequencies of 120 cycles per second. At a glance it appears to be a conventional audio amplifier, differing mainly in the fact that the choice of capacitors and resistors in the plate and cathode circuits of each stage has been made to provide a band pass characteristic to help in the suppression of shot and thermal agitation noises. The amplifier is terminated with a tuned LC circuit and the discriminator; the LC circuit acts to provide a narrow band pass, and the discriminator detects the 120-cycle modulation component to the substantial exclusion of the combined effects of shot and thermal agitation noises. See figure 5.

Considerable effort has been spent, however, in designing the amplifier so that it is free from 120-cycle hum and pickup from various other components of the detector assembly. Such pickup, being at the same frequency and at nearly the same phase as the signal returned from the clouds, would introduce false signals of serious magnitude.

In this connection, the second, third and fourth stages of the amplifier are operated at low plate potentials to minimize the load on the power sup-

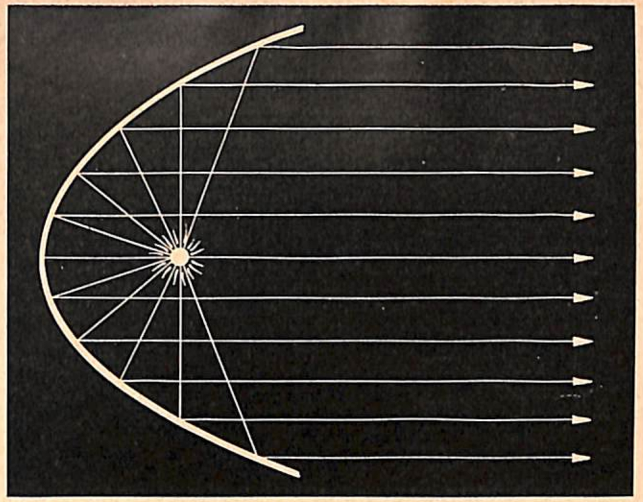


FIGURE 3—*Action of a parabolic reflector and a point source of light located at the focal point.*

ply filtering system, and thus provide d-c with a smaller ripple component. All amplifier filaments are heated by filtered d-c, provided through the use of a selenium rectifier and filter circuit. The preamplifier stage and p-e cell assembly are sealed in a sheet steel case and are thus magnetically and electrostatically shielded to prevent them from picking up voltages due to stray fields.

The effects of microphonism, another source of 120-cycle false signal introduced by the physical vibration of magnetic cores in the power supply and driving motor and carried to the amplifier through the main frame, are kept to a minimum by the use of several precautions: a—soft-rubber shock mounts are used on the preamplifier tube socket; b—the driving motor and selsyn generator beds are mounted on springs; c—the selsyn is fitted with a heavy flywheel and a soft-rubber shaft coupling; d—the motor is coupled to the detector drum with a spring drive; e—the drum itself is a casting, made heavy to give it a long natural period of vibration; f—all iron-core elements have been eliminated from the amplifier to reduce the possibility of magnetic pickup of 120-cycle hum. The tension of the spring drive between motor and drum is critical. For that reason no attempt should be made to repair the spring should it break. Rather, a new spring should be installed. All these precautions are necessary if the amplifier is not to amplify false signals at 120-cycles.

The discriminator is of great interest and will be discussed at length. Through the use of the discriminator the desired signal is extracted from the combined shot, thermal agitation, and other extraneous noises. In order to extract the signal, another voltage, known as the phasing voltage, is added in the discriminator to create a bias which in turn controls the recording equipment. Neither signal, noise, nor phasing voltage alone will create this bias; only a combination of true signal and phasing voltage will pass a signal into the recorder.

See figure 6. The phasing voltage is rectified 60-cycle a-c. It thus has a wave form very nearly the same as that of the signal voltage. Its phase has been adjusted by use of a conventional phase-shifting network so that its voltage is in phase with the signal voltage.

The phasing current flows as indicated by the dashed arrows through transformers T1, T2, and T3. Note that the phasing current is equal and opposite in each half of the secondary winding of T1 and is flowing in opposite directions in the primary windings of T2 and T3. There will be secondary currents in T2 and T3 due to the phasing current alone, but these currents will be rectified by V1 and V2 in a like manner, creating voltage drops across R2 and R3. These voltages will be equal and opposite, however, and will therefore cause no change in bias applied to the grids of V3. The signal voltage is applied to the primary

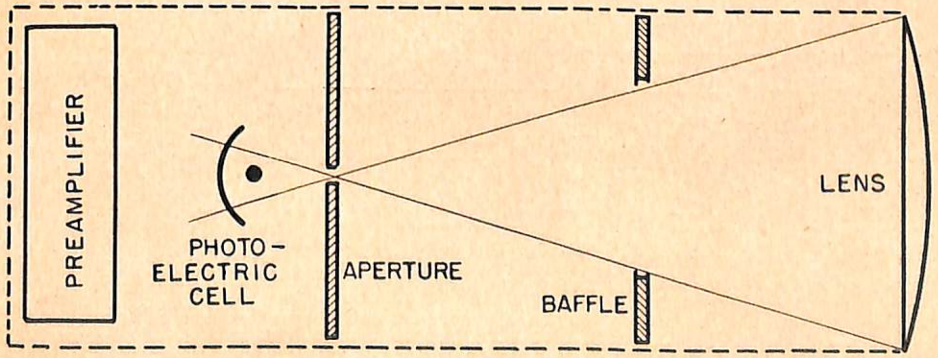


FIGURE 4—*Cross section diagram of detector optical system and p-e cell.*

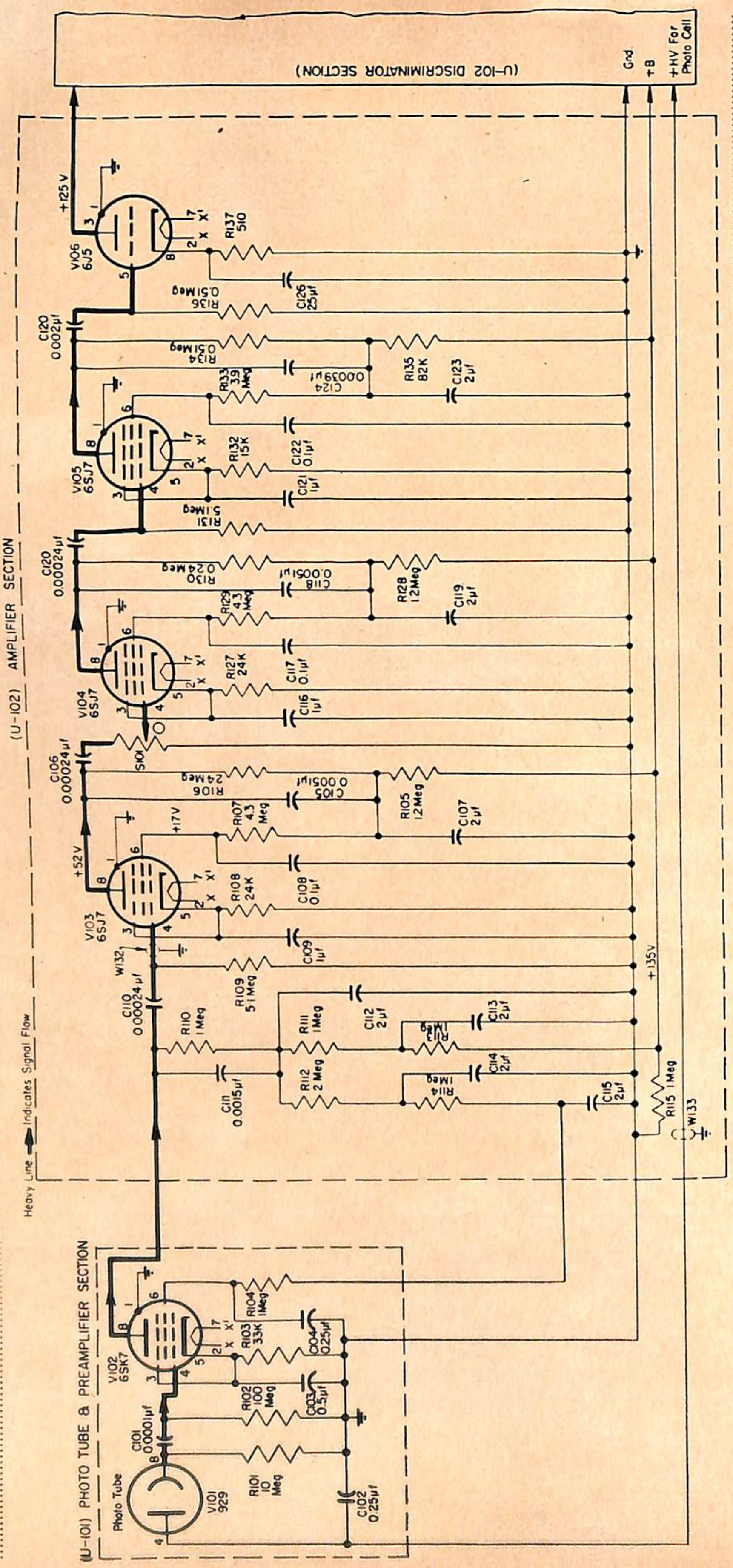


FIGURE 5—*Schematic diagram, pre-amplifier and amplifier.*

of T1. Instantaneous currents will be induced into the secondary of that transformer, as indicated by the solid arrows. These currents will flow in the primaries of T2 and T3, adding to or subtracting from the currents already in those primaries due to the phasing currents. In the primary of T2 the signal and phasing currents will subtract; in T3 they will add.

Obviously, with both signal and phasing voltages applied, there is a heavier current flowing in the primary winding of T3 than in T2. This heavier current causes a greater voltage to be applied to the plates of V2 than V1, and a heavier current to flow through R3 than R2. The current through R3 is of adequate magnitude and of proper direction to create a voltage drop sufficient to overcome that developed across R2 and in addition provide an over-all bias to the grids of V3, making one more negative than the other.

The tube V3 has balanced plate and cathode circuits. The plate is held in balance because plate voltage supply is fed into the center tap of the output transformer T4. The cathode is held in a balanced condition through proper adjustment of R7, which is adjusted to the point where equal currents flow from ground to each cathode with no signal at the grids. With this basic balanced condition obtained, any unbalance provided by one grid of V3 being made more or less negative than the other will cause a greater current to flow through one or the other of the triode sections, and create a voltage differential in the output transformer.

Plate supply to V3 is unfiltered d-c. With both triode sections of V3 balanced, plate currents cancel in the primary of T4 and no signal is induced into the secondary. When the grids of V3 become unbalanced by action of the discriminator, however, that unbalance is carried into the secondary of the output transformer and a voltage, a component of the unfiltered supply, is provided which operates the recorder to which it is connected.

Since signal alone can not operate the discriminator but depends on the addition of the phasing currents, then the noise developed in the input to the amplifier cannot by itself operate the discriminator. Such noise voltages being of random character, they can not be combined with the phasing voltage to provide the necessary bias differential at the grids of V3. The noise, then, is effectively eliminated.

ML-336/GMQ-2 CEILOMETER RECORDER

A high-powered light source and a means of detecting the reflection of light from the clouds are useless if no means are provided for determining the angle from the horizontal to the spot in the clouds and the magnitude of the received signal. The ceilometer recorder is therefore provided to perform those two functions.

The recorder makes use of two graphs: an inkless angle indicator and a signal amplitude recorder in the form of a recording voltmeter, wherein a continuous graph is made in ink of the input voltages. The two graphs, located side by side in the face of the recorder, are drawn simultaneously, one giving the vertical angle to the cloud base, the other giving the magnitude of the received signal. See figure 7.

The angle is recorded on the left-hand graph. A cam-operated stylus strikes through a typewriter ribbon whenever the return signal exceeds a threshold value. The location of the stylus at that moment, and therefore the location of the marks made on the recording paper, is governed by the selsyn receiver as it follows the motions of the moving drum on the ceilometer detector.

The special paper on which these graphs are drawn is provided in rolls. It is fed at any one of three fixed rates, three, six or twelve inches per hour, by installation of different drive gears.

Figure 7 shows the graphs made by these two mechanisms. Note that the left-hand graph is stepped off in degrees and the right-hand graph in fractions of a milliampere. By laying a straightedge horizontally across the two graphs it may be shown that for every mark on the left-hand graph there is a strong indication of a signal on the right-hand graph. In the case illustrated, the strongest signals were received when the detector was elevated to an angle of 60 to 64 degrees from the earth's surface.

Note that the indication was received as the detector drum was moving downward as well as upward. The rate of decline of the detector drum is the same as the rate of climb; six minutes are required for it to move from horizontal to vertical, and vice-versa. Twelve minutes are required to complete one cycle of events.

The altitude to the clouds which gave the reflection noted in figure 7 may be computed easily. From any table of the trigonometric functions determine the tangent of the angle. In this case the angle is 60 degrees and the tangent of that angle is 1.732. The distance separating the projector and the detector is 1000 feet.

$$a = b \tan 60 = 1000 \times 1.732 = 1{,}732 \text{ feet}$$

The altitude obtained is the altitude at which the return signal first became strong enough to trip the threshold relay and start the recorder operating. The graph, figure 7, shows a rather long signal (four degrees). The altitude to the clouds using the angle of 64 degrees works out to 2,050 feet, and represents the maximum altitude from which a threshold signal was received. The lower altitude is the correct one to use, since it is of the bottom of the cloud, not the top. In drawing this graph, the detector continued to receive indications as it moved through the arc between 60 and 64 degrees because the cloud was not so dense as to reflect all light from its nearer surface, but rather diffused the light, reflecting a little from each of the tiny particles of moisture which constituted it.

In some cases two or more indications, each at a different altitude or angle may be received, each from a small cloud of light texture through which part of the projected beam passes, only to be reflected again from the clouds above. In such cases the thickness of the clouds may be determined by subtracting the altitude to the base of the cloud from the altitude of the top. In the case cited above, if there were reason to believe the reflections were being received from a layer of clouds with open sky above, the thickness of the layer would be estimated at 218 feet.

The advantages of having a signal-magnitude recorder as well as an angle recorder are worthy of note. Since the magnitude of signal is a rough indication of the texture of the cloud, if the signal is sharp and strong the cloud is obviously dense; if the signal is weak and broad, there is a thick layer of haze which is attenuating the power in the projected light beam without returning a strong signal from any one altitude to trip the threshold relay and thus allow the angle recorder to operate. Fog, then, extending from the earth upward ("ceiling zero") should return a signal decreasing steadily as the angle increases, for as the angle increases the projected beam travels through an increasing thickness of fog and thereby becomes weaker, and the reflections pass downward through the same increasing thickness of fog and are likewise attenuated. Under these circumstances the angle recorder might draw a graph from zero degrees up to 30 or 40 degrees then stop abruptly because the return signal no longer was beyond threshold value. The same set of conditions might hold if there were a thick layer of light fog whose lower limit had

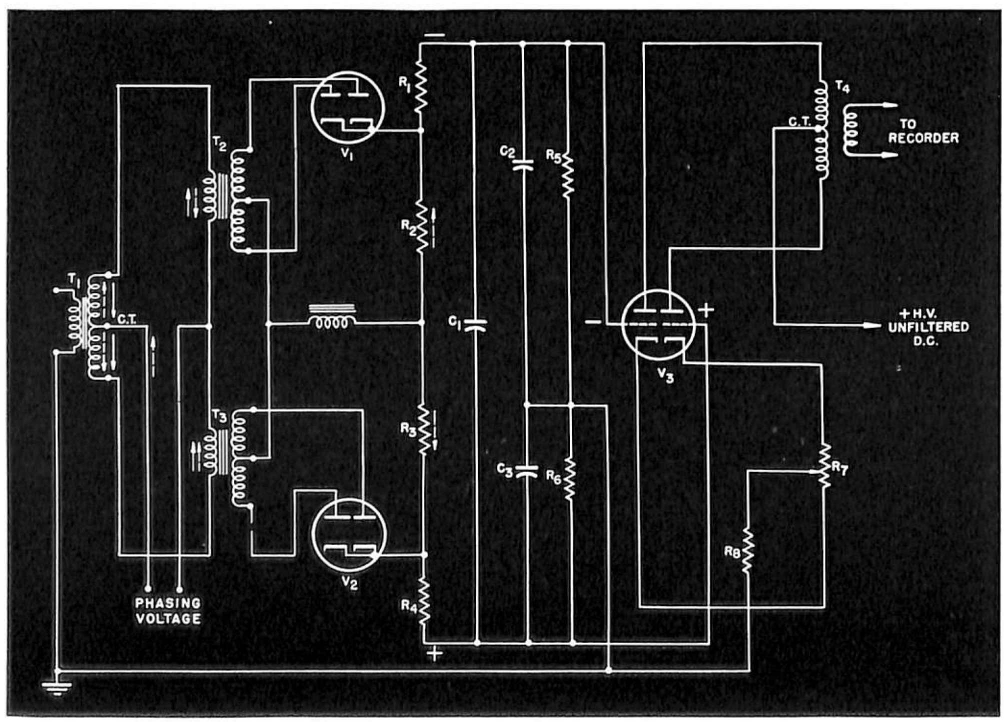


FIGURE 6—*Simplified schematic diagram of discriminator.*

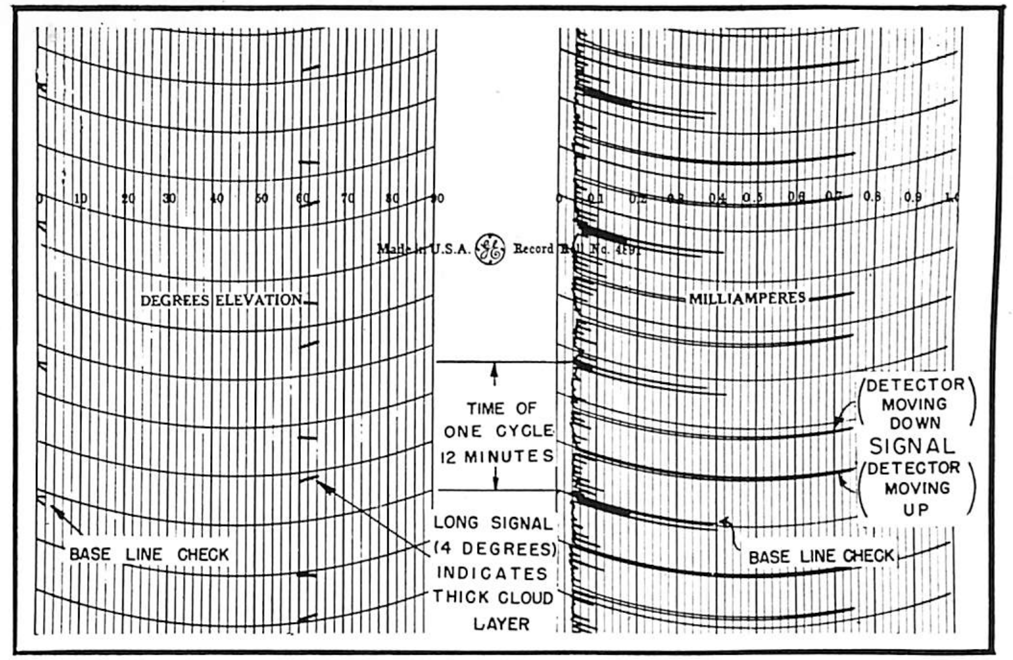


FIGURE 7—*Typical graphs made by ceilometer recorder.*

an altitude of perhaps 2000 feet and an upper limit of 5000 feet. In each of these cases the continuously-running graph of signal magnitude would be a useful index of conditions, and experience in interpreting it with respect to the angle indicator should promote a much better analysis of the cloud situation.

A conventional milliammeter is installed in the detector case. Paralleled with the signal recording unit, it is provided to allow for manual operation of the ceilometer. By training the detector drum by hand and observing the signal magnitude on the meter, more accurate determination of the elevation angle may be made at high ceiling altitudes.

The signal magnitude recorder is also of value to the maintenance man, for by it he can determine, on a relative scale, the efficiency with which the amplifiers and projector are operating, and whether the discriminator is performing its design function.

As time goes on, more experience will be gained in the use of the Photoelectric Ceilometer. Failure reports will indicate weak points in the equipment, suggestions will be made and alterations performed. When it becomes available, information leading to better maintenance and operation of the equipment will be published.

BLACKLITE SONAR DIAL ILLUMINATORS

Ships and field activities in need of 4-watt 6-inch "blacklite" bulbs for sonar dial illumination are requested to procure them through their local supply office from Bayonne or Oakland stocks, whichever is the nearer.

These blacklites are of two double-end contact types and are listed under the following stock numbers: N16-L-1108—Single pin and ferrule type ends. For Model QGA, replacing part number 745-146 (SubSig) in both stacks, circuit symbols I-301, -2, -3, -4 and I-701. N16-L-1110—Double pin ends. For Model QGB, replacing part drawing number W-306587-139 (RCA) circuit symbols I-801, -2, -3, -4, and -5, and also for the Sangamo recorders (CAN-55112, CAN-55134, etc.) part number 803-005 circuit symbol I-102.

These lamps will operate with any 4-watt 110- to 120-volt, 60-cycle a-c ballast and starter. The Model QJA dial illuminators are similar to stock number N16-L-1110 except that they have a frosted white glass envelope instead of the blacklite type. Although the N16-L-1110 illuminator can be used in the Model QJA equipment, it should be noted that difficulty might be experienced in reading the non-fluorescent dials.

Telephone HANDSET HOLDERS

Two telephone handset holders designed especially for Naval Shipboard use have been distributed in quantity to Electronic Supply Offices for use with all applicable shipboard electronic installations. One of these carries the Navy Type Designation -51085, and the other does not carry any navy type number but is identified only by the Federal Standard Stock Catalogue number 17-B-33793.

The 17-B-33793 handset holder should be used for all electronic installations which do not require holders that contain switches and terminal boards (as the types -51009 and -51085 do). This holder

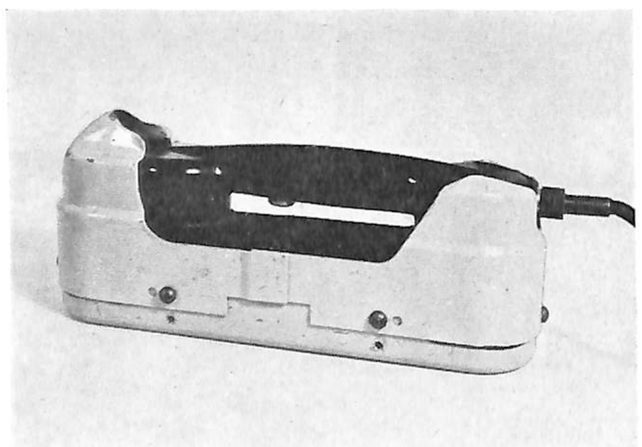


Figure 1—*Federal stock number 17-B-33793 handset holder. When used with a standard handset, the screws to the cover of the holder must be relocated to provide additional space for the handset.*

has been shock-tested and adopted as a standard item for interior communication and electronic shipboard installation. It is anticipated that this holder will eliminate the possibility of handsets becoming detached from their holders under the shock of gunfire. Also, the 17-B-33793 handset holder is adjustable and will accommodate practically all types of handsets now in use aboard Naval vessels.

The navy type -51085 handset holder, which supersedes the navy type -51009 holder, is shown in figure 2. The type -51085 holder, which contains a switch and terminal board, should be used only in vessels and spaces specifically designated by the Electronic Equipment Type Allowance Book (NavShips 900,115) or as otherwise directed. Sufficient quantities of these holders to fill authorized needs, however, have been distributed to the Electronic Supply Offices, and use of the superseded types -51009 and -510009-A holders should be discontinued.

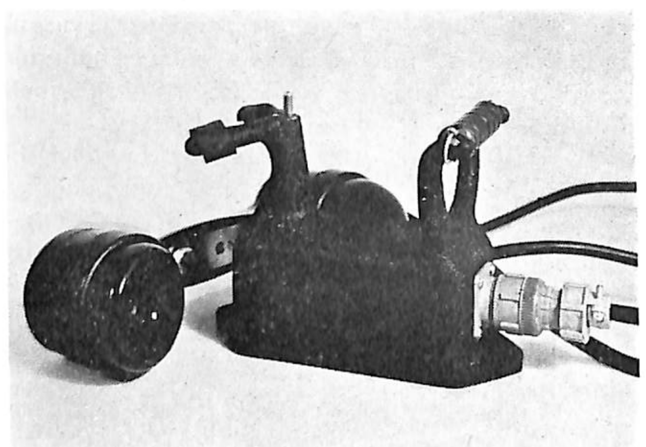


Figure 2—*Navy type CRV-51085 handset holder shown with handset CRV-51081 attached.*

Electronic requirement figures for the 17-B-33793 holders should be submitted to the Bureau of Ships in the usual manner, that followed for government-furnished electronic material. All future requisitions and requirement figures for telephone handset holders should specify either the type -51085 or 17-B-33793 or both, as applicable. The procurement and use of all other types of holders are now to be discontinued.

Automatic Carriage Return For Radio Teletypewriters

• • • • • • • • • • •

By B. S. Swezey

Reprinted from Bell Laboratories Record

■ Teletypewriters have been employed over radio channels to a limited extent ever since World War I, but their use greatly increased during World War II. Although disturbances that may mutilate a character are far more common over radio channels than over land lines, the occasional mutilation of a character is ordinarily of no great concern if the message is being recorded on a continuous tape at the receiving end, since the characters preceding and following the mutilated one usually permit the message to be correctly interpreted.

During the recent war, however, page teletypewriters were used at the receiving terminals of radio channels for directly recording the messages, and they are more seriously affected by hits on the radio path. Where page machines are used, two codes are sent at the end of each line to return the type carriage to the beginning of the line and to feed up the paper. When the sending operator reaches the end of the line, he depresses a "carriage-return" key and then a "line-feed" key, and each of these acts sends a code that causes the receiving teletypewriter to perform the operation indicated. Should a hit mutilate either or both of these codes, a portion of the message will be lost until the next carriage-return and line-feed signals are received. If the carriage-return signal is received, but not the line feed, the next line will be typed over the one already typed, probably making both illegible. If the carriage-return signal is mutilated, but the line feed is received correctly, all of the next line will be typed at the end of the next line. If neither carriage return nor line feed is received, the next line will all be typed at the end of the line just completed.

Teletypewriter codes comprise five time intervals during which a pulse may or may not be present, and the combinations of pulse or no pulse in five positions provide thirty-two different codes. For carriage return, the code used is a pulse in the fourth position and none in the others, whereas a line-feed code has a pulse in the second position, and none in the others, as illustrated in figure 1. These signals are multilated when disturbances cause the elimination or addition of pulses. In either case, the carriage-return and line-feed code will not be received; some other code will take their place.

Other types of garbling can take place, however, because disturbances over the radio path, instead of eliminating one or both of these codes, may cause them to appear at the wrong time. The signal for some other code may be mutilated in such a way as to make it appear as a carriage-return or line-feed code. Thus the letter R, for example, having a pulse in the second and fourth positions, would become a carriage return if the pulse in the second position were lost, or would become a line-feed signal if the pulse in the fourth position were lost. There are many such codes in which a substitution would transform to carriage-return or line-feed codes. With a carriage-return signal wrongly appearing in the body of a line, the receiving teletypewriter would print the remainder of the line over the first part, making both illegible.

To avoid such mutilation of messages sent over radio paths, the Laboratories initiated the development cooperatively with the Teletype Corporation of arrangements that would insure proper carriage

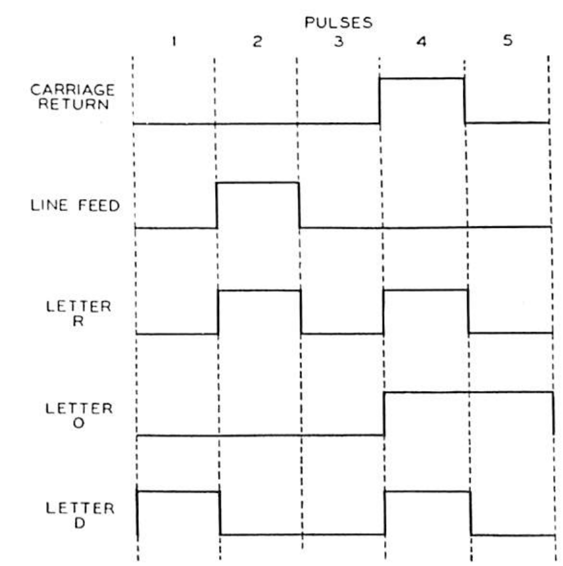


Figure 1—*Teletypewriter codes are built up from the presence or absence of a pulse in five intervals between start and stop pulses marking the beginning and end of each code. The codes for carriage return, line feed, and the letters R, O, and D are shown above.*

return and line feed regardless of mutilation of the signals sent for this purpose. The arrangements provided to take care of this situation were the outgrowth of some previous work done by the Laboratories and the Teletype Corporation. Two major changes were incorporated in the machine. One was to modify the apparatus at the receiving end so that, on receipt of the carriage-return signal, both carriage-return and line-feed operations would be performed at the receiving teletypewriter. This makes it unnecessary to transmit the line-feed signal at all. Instead, and to allow time for the physical return of the carriage, the carriage-return signal may be followed by one or more of the "letter" signals.

This change in itself is adequate to insure the proper action of the receiving teletypewriter most of the time. To insure proper carriage return and line feed even though the carriage-return code were lost, the second change was made. It consisted of a mechanical arrangement that operated the carriage-return and line-feed mechanisms when the type carriage reached the end of the line whether a carriage-return code was received or not. With these two changes, the multilation of messages by ordinary disturbances over the radio path was considerably reduced. If the carriage-return signal is lost, the mechanism on the receiving teletypewriter will return the carriage and operate the line feed at the end of the line, and should one be formed by a disturbance, the typing would merely continue on the next line, and no illegibility would result.

The only over-typing that can occur with these new arrangements is of one or two characters during the time the carriage is returning. As already mentioned, a short interval is required for this return, and in normal practice it is provided by the succeeding line-feed operation. When the carriage-return code is mutilated, however, or appears incorrectly in the body of the line, very little time for the return is allowed, and as a result, the following one or two characters may be printed "on the fly," and will thus appear as over-printed characters on one or the other of the two lines involved. Knowing how this error occurs, however, the receiving operator can ordinarily readily locate and identify the over-printed characters.

The sort of over-printing that may occur on radio circuits without these modifications, and how illegibility is almost entirely eliminated with them, is illustrated in figures 2 and 3. These show an artificial three-line message correctly printed at the top, and below, the effects of various forms of mutilation before and after the new devices were installed.

```
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY 1234567
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY

NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY 12345679

NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY

NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY 1234567
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTYO
                                                                   NOW IS

NEWNISOTHEMEIME THE AID GDOTHE PARTY 1234567
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY
NEWTOSTHEEATIMOFFOREAPARTOOD MEN TO C
```

Figure 2—*A three-line teletype message received correctly at the top and mutilated in the three other views. In the second, a 9 (upper case O) was received in place of the carriage-return code at the end of the first line, and as a result the entire second line piled up in the last space of the line. In the third, an O was received in place of the carriage-return code following the last word of the second line, and as a result only two words of the third line appear. At the bottom, a carriage-return signal was received in place of the D in GOOD in the first line, which resulted in obliterating all the characters up to that point, and in the third line a carriage-return signal was received in place of the O in COME, resulting in a similar garbling.*

```
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY 1234567
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY

NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY 1239567
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY
                                                     O for "Car. Ret."
                                                     (9 in upper case)

NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY 1234567
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTYONOW IS
E TIME FOR ALL GOOD MENHTO COME TO THE AID OF THE PARTY
                       H of "the"                 O for "Car. Ret."
                                                               T of "the"

                            Car. Ret. for "D"
NOW IS THE TIME FOR ALL GOO
 MEN TO COME TO THE AID OF THE PARTY 1234567
NOW IS THE TIME FOR ALL GOOD MEN TO COME TO THE AID OF THE PARTY
NOW IS THE TIME FOR ALL GOOD MEN TO C
ME TO THE AID OF THE PARTY             Car. Ret. for "O"
```

Figure 3—*The same transmission errors that occurred in figure 2 occur here, but this receiving machine is equipped with the automatic features for carriage return and line feed. As a result, the only harmful effect is the over-printing of two letters as the carriage returns or a single added (second from top) or dropped letter (bottom).*

For radio teletypewriter circuits employing page printers at the receiving end, these automatic carriage-return features are very helpful, and well proved their worth during the war. For wire circuits as used by the Bell System, however, they have little advantage and represent an expense that must be added to the cost of service. It is always desirable to transmit a carriage-return and a line-feed signal so that these operations will be made to take place at the end of a word rather than at the actual end of the line, that is, when 72 characters (normal length) have been typed. The time devoted to the sending of the carriage-return and line-feed signals is largely utilized by the receiving machine in performing the operations which cause the carriage to return and the paper to feed up. If this time were not allowed, and dependence placed solely on the automatic features, there would probably be over-printing on almost every line. Such a degree of over-printing would normally be considered undesirable, particularly on land lines where distortions that cause a carriage-return or line-feed signal to be lost are so infrequent as to be of only minor concern. These automatic features, therefore, while very advantageous for the special conditions they were designed to meet, are not contemplated for ordinary Bell System service.

New Design of FM Receiver Detector

■ A recent simplification in the field of FM receiver design has been announced by the Industry Service Division of the Radio Corporation of America. Although the impact of this new design will probably be felt more heavily in the field of home receiver design and marketing than in Navy equipment, the design itself presents many features which should be of interest to the readers of ELECTRON.

The new development consists of an improved design of the FM detector circuit, which converts the intelligence-bearing frequency variations of the i-f voltage into the corresponding audio output. Advantages include elimination of the limiter stage and reduction in the i-f gain required.

The most commonly used conventional discriminator circuit suffers from the fact that it is sensitive to amplitude variations in the i-f input to the detector, as well as to the worthwhile frequency variations. See figure 2. Any extraneous amplitude variation can, therefore, be impressed on the signal, and will appear as distortion. Shearing the i-f signal off at a prescribed amplitude level with limiters will overcome the obstacle, but necessitates additional tubes in the limiter circuits as well as additional i-f gain. This can be tolerated, but anything that can be done in the way of reducing components is found advantageous in modern competitive marketing. Accordingly, investigations were carried out over a period of many months, resulting in the new detector, which is insensitive to amplitude variations and therefore eliminates the limiter stages and reduces the amount of i-f amplification required. From the nature of its operation, this improved device has been given the name, "Ratio Detector."

Closely resembling the conventional detector as it does, the ratio detector is best described by explaining the former. Both detectors utilize the characteristics of an i-f output transformer uniquely connected as shown in figures 1 and 3. A tuned-circuit secondary is used in this phase shift circuit, often with a tuned primary. As will immediately be seen from the figure, the center-tap of the secondary is directly connected to one end of the primary. Hence, the voltage e_{ab} between points a and b is the sum of the primary i-f voltage and that of the left half of the secondary. The voltage of the right half of the secondary will add to that of the primary to build up the voltage e_{bc} between points b and c.

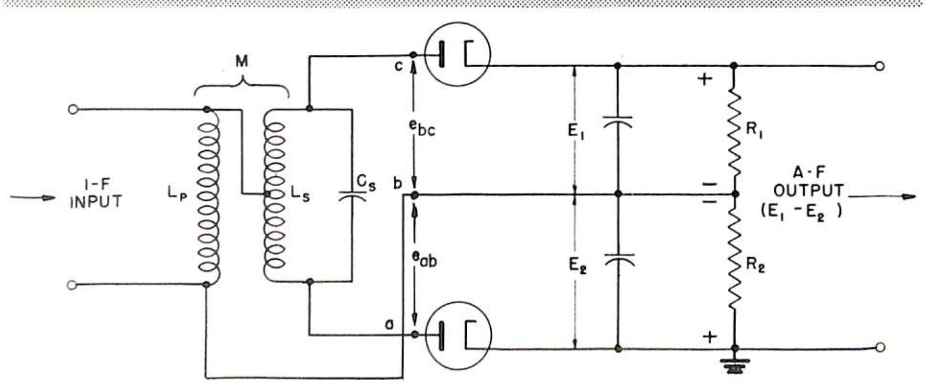


FIGURE 1—*Standard discriminator circuit. This circuit is sensitive to both AM and FM and must therefore be preceded by a limiter circuit.*

At resonance, the secondary voltage is 90° out of phase with the primary voltage. When the i-f frequency goes off resonance, however, the secondary voltage is more or less than 90° out of phase, depending on whether the frequency increases or decreases. This change in phase makes the two i-f voltages e_{ab} and e_{bc} unequal in magnitude, as can be shown by vector diagrams. The inequality depends on the amount by which the frequency is off resonance. The difference between the magnitudes of these summation voltages thus depends on the frequency, and forms the basis of the detector. If these two voltages are now rectified with diode detectors and the resulting varying d-c voltages combined in opposition, the output $E_1 - E_2$ will be directly proportional to the i-f frequency deviations. Such is the standard discriminator, illustrated in figure 1.

Contrast this with the new ratio detector, shown in figure 3. Three changes will be noted. First, the connections of one diode have been reversed, so that the condenser voltages now add instead of oppose. Next, the ground connection is at a different point, and the output is taken off of different terminals. Finally, and of most importance, the condenser voltage sum $E_1 + E_2$ is held at a constant value by some form of stabilizing device, indicated but not shown.

In this circuit, although the sum of the voltages $E_1 + E_2$ remains unvarying, the *ratio* of the individual voltages E_1 and E_2 varies in the same way as the ratio of e_{ab} and e_{bc}, independently of amplitude changes. Since the above sum is stabilized, amplitude variations have no effect. Feeding the output from the terminals chosen furnishes a voltage equal to $(E_1 - E_2)/2$, proportional to the frequency deviation.

Two means may be employed to hold $E_1 + E_2$ constant. The somewhat obvious expedient of a battery may be used, or a large condenser may be shunted across the voltage $E_1 + E_2$. The large condenser will not actually hold the voltage strictly constant; if it is large enough to lead to a time constant of about 0.1 or 0.2 second, however, it will hold the voltage relatively constant with respect to either i-f or audio voltages. Thus, the ratio detector action is still maintained. Such slow variations in $E_1 + E_2$ that do occur will be manifest merely as variations in audio volume level. Far from being detrimental, these variations are actually beneficial, for they are perfectly adapted for a-v-c control of the i-f gain. In actual practice only the condenser is used, since battery stabilizing requires a signal at least great enough to overcome the battery bias.

The new ratio detector is not without its faults. Small secondary effects are important, since ratio detector is really a type of bridge circuit depending on proper balancing of the components for smooth operation. Unless these secondary effects are compensated for, this circuit will not completely prevent amplitude modulation present in the i-f signal from affecting the audio output. Such amplitude variations may be introduced by fading, cancellation by multiple-path reflections, selectivity in the r-f or i-f stages, or unbalance in the detector itself. Another form of response to amplitude variations, one which is dependent on the input signal level and is very troublesome, is known as "residual a-m output."

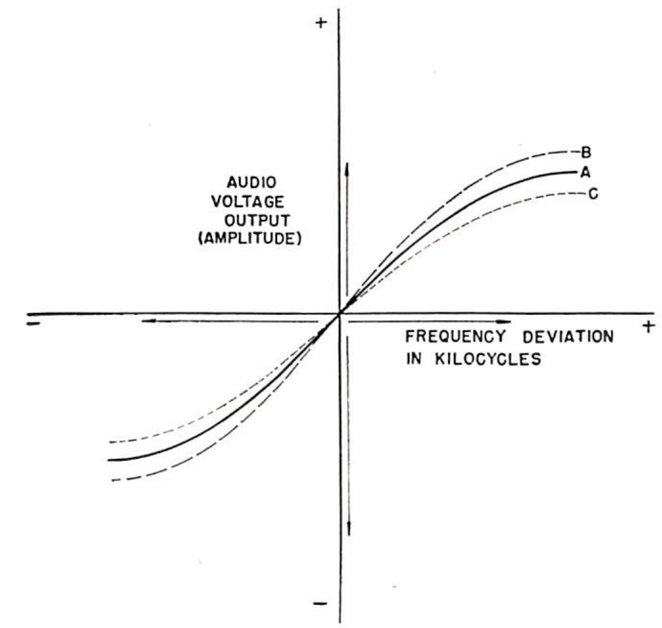


FIGURE 2—*Characteristic curves for standard discriminator circuit. Curve A represents standard i-f signal amplitude; curves B and C show the effects of changing the magnitude of i-f signal.*

The consideration of such secondary effects brings up practical aspects of ratio detector design and application. First, in order to compensate for the residual a-m mentioned above, resistance is added to the stabilizing condenser, "destabilizing" the circuit just enough to compensate for and cancel out this a-m. For this feature to work, the primary-secondary voltage ratio must lie within a certain range, a requirement easy to fulfill. The residual a-m may also be eliminated by moving the tap on the i-f transformer secondary slightly off center.

In general, experiments have shown that, for optimum performance, the ratio detector should be designed as follows:

1—Stabilizing condensers should give a time constant of 0.1 or 0.2 second. This calls for values of a few microfarads.

2—High values of secondary Q and low values of diode load resistances are best for efficiency at low signal levels.

3—Low plate-resistance diodes are preferable, such as the 6AL5 (14 milliamperes per diode at 4 volts). If it is higher than that of the 6H6 (3.5 milliamperes per diode at 4 volts), the circuit will not perform.

4—The secondary L/C ratio should be as high as possible, consistent with keeping the effect of stray capacity negligible.

5—The primary L/C ratio should be as high as possible to achieve good sensitivity.

6—The secondary Q as well should be as high as possible. At i-f frequencies of ten megacycles or so, this means a Q of 75 to 100.

7—Fortunately, the load resistors are not critical, as long as they are low enough.

Typical component values for a good design are:

1—Stabilizing condenser = 8 μfd. Time constant = 0.1 second.

2—Residual a-m compensating resistor = 47 ohms.

3—A-f output at a 75-kilocycle deviation for 100 millivolts input = 0.7 volt r-m-s.

4—Distortion at 100% modulation (75 kc deviation) is 2.5%. Distortion at 30% modulation (22.5 kc deviation) is 0.75%.

5—Primary: Unloaded Q = 89.
Operating Q = 40.

6—Secondary: Unloaded Q = 89.
Operating Q = 21.

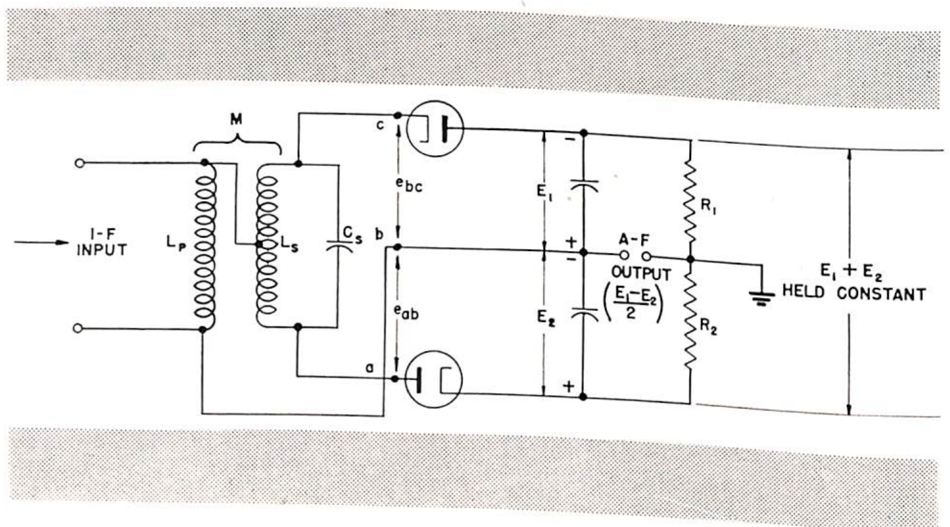
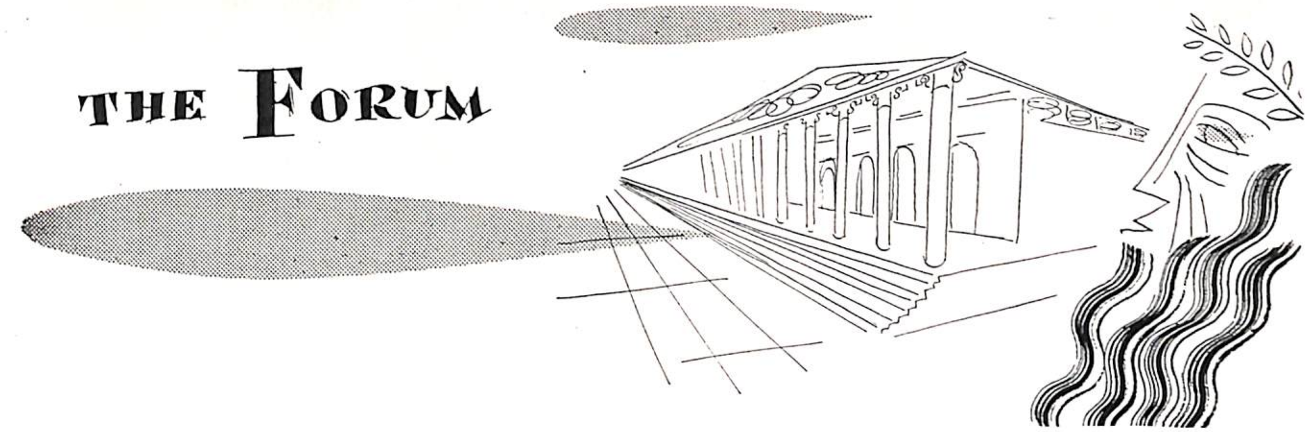


FIGURE 3—*The Ratio Detector. Note similarity to standard discriminator shown in figure 1. This circuit is frequency-sensitive, but substantially eliminates the AM components.*

Although the value of the ratio detector can by no means be classified as dubious, it does not effect any major improvements. It does, however, eliminate the limiter tube and its associated circuit, permits quieter operation between stations, supplies a better a-v-c voltage source, and cuts down the i-f gain requirements. In the RCA laboratories a detector was operated satisfactorily, even at low levels, with only one i-f stage.

In concluding, we might state that as the FM ratio detector seems to simplify somewhat the design of FM receivers, it is expected to make its appearance in some of the new FM sets. As further improvements and refinements are made, the circuit may find its way into the design of navy equipment.

THE FORUM



MK-12 RADAR FIELD CHANGE

By ROGER C. HINES, *ETM 3c, USS Duluth (CL-87)*

I would like to suggest that a field change be made on the Mk12 radar to include a 0 to 500 volt d-c voltmeter in the Regulated Rectifier circuit. This meter would give a constant voltage supply reading and thereby assist the technician in the performance of rapid and efficient maintenance. A similar set-up already incorporated in the Mk 8, Mk 28, etc. has proven very satisfactory.

At present in the Mk 12 radar it is necessary that the technician hold meter leads on the terminal board and at the same time make his adjustments. This is very inconvenient and the suggested change would certainly be welcomed by many of our maintenance men.

The change could very easily be accomplished by cutting a hole in the right hand corner of the Regulated Rectifier drawer and inserting the meter. The meter could then be connected in the circuit by connecting one side to terminal eight on the terminal board and the other side to ground.

Bureau Comment: It is not the policy of the Bureau to discourage such suggestions as the above as they indicate an interest which over a period of time will greatly benefit the Navy. However, the day of field changes for the Mk-12 radar has passed unless it can be shown to be an operational necessity. This proposed modification would promote a convenience to maintenance personnel but can hardly be considered a necessity.

It is suggested that some means of securing the test meter leads to the test points when making adjustments in output voltage be devised. The use of leads with alligator clips on the ends would be one possible method.

GREAT CIRCLE BEARINGS

Fred B. Gallien, CETM, USCG

In reference to the article in July ELECTRON by Lt. Comdr. I. L. McNally, "Calculating Great Circle Bearings." It is suggested that this article be submitted to "QST" for publication (minus error in subtraction—360° -61° 37.5′ = 298° 22.5′, not 198° 22.5′.

As an amateur radio operator I have often puzzled over the subject of determining great circle bearings without the aid of azimuthal maps. I believe Commander McNally's contribution would be greatly appreciated by the amateur fraternity.

Bureau Comment: Lieutenant Commander McNally states that many amateurs are already using the system, as he has given it to many friends in that field. He thanks you, however, for the suggestion.

The staff of ELECTRON apologize for the typographical error and hope that it has not caused too much trouble to the readers.

VOLUME CONTROL DETAILS

The article, "Volume Control for Type-49546 Speakers" in the June 1946 issue of ELECTRON included a statement to the effect that vessels and activities finding it necessary to make the volume control modification should contact the Bureau for the approved method. This is no longer necessary as the entire procedure together with detailed drawing has since been published. It may be found in the Communication Equipment Maintenance Bulletin on pages TYPE: 13 and TYPE: 14.

When this change is made its completion should be reported to the Bureau on an NBS-383 form and recorded on an Electronic Equipment History Card, NavShips 536 and on a Field Change Report Card, NavShips 537.

Methods and Purposes of Screening Techniques

■ In the past few months, numerous questions and suggestions have been received by the Electronic Supply Office concerning the delay in receipt of material. It is the purpose of this article not to justify this reported condition, but to clarify the situation and explain the means by which requisitioning activities can themselves aid considerably in effecting the most expeditious procurement of material. Only by understanding the methods and purposes of the Technical Screening Section of ESO can the various supply branches and distribution points fully appreciate the issue and procurement problems confronting the electronic supply system. In the following paragraphs an attempt will be made to answer most of the procurement questions received by ESO from the various requisitioning activities.

PROCUREMENT CYCLE

In the event that a requested item is not apparently available in the electronic supply system, the requisition is forwarded from the primary distribution point (NSD, Bayonne) to the Electronic Supply Office for final procurement action.

The Technical Screening Section of ESO will then analyze the request and take one of the following steps:

(1) Determine availability in salvage.

(2) Determine availability in spares of other equipment models which may be included on the allowance list of the requisitioning activity.

(3) Determine availability of equivalents or satisfactory substitutes in the electronic supply system.

(4) Establish and replenish only preferred value items to afford widest material application and distribution. This is part of the item standardization program at ESO to eliminate from the electronic supply system those items presenting purchase difficulties and exorbitant expense. The selection of such standard items is based on Field Reports, Joint Army-Navy Specifications, and consultation between engineers at ESO and equipment contractors. In no case will an equipment be modified by an ESO substitute. Only alternate items will be supplied which will not change the electrical status of the equipment or necessitate any physical modification thereto.

(5) Suggest methods for fabrication of mechanical parts within the scope of Naval Shipyards or tenders. In most cases, such fabrication can be effected more rapidly than the parts can be purchased commercially. In addition, the economy factor must be considered.

(6) Determine availability of defective parts rather than supply an entire item. Relays are one of the more profound examples of such items. Coils or contacts only should be requested where their replacement in relay repair is practicable.

(7) If, in analyzing the above, the material or its equivalent is not available in the electronic supply system, or if mechanical fabrication is not possible, purchase action will be initiated.

It is not the intent of the methods outlined above to delay the procurement of electronic items but rather to effect more expeditious handling of requisitions to make more readily available the widest distribution of material. The success of this aim depends largely upon the information supplied on the requisitions.

INFORMATION REQUIRED

(1) If an ESO stock number is available, the following applies:

ESO stock number.
ESO item description.
Equipment model and symbol or item number.
Contractor and contractor's reference number.
Manufacturer and manufacturer's reference number.

(2) If an ESO stock number is not available, the following applies:

(a) Advance number, if applicable. (Refer to "ESO Newsletter" Volume 1, No. 2.)

(b) Item description in accordance with "Joint Army-Navy Manual of Standard Descriptions for Electronic Equipment and Material, JANP 109." If a complete description is not possible, all the information available should be supplied.

(c) Equipment model and symbol or item number.

(d) Contractor and contractor's reference number.

(e) Manufacturer and manufacturer's reference number.

(f) Navy type number.

(3) In cases where the material requested does not apply to a Navy model equipment, the specific authorized application should be indicated: i. e., special projects.

NEED FOR INFORMATION

Many questions have been received at ESO as to the necessity for including on requisitions all the information as outlined. The following list shows the need for this information:

(1) Equipment model and symbol number:

(a) The possibility of error does not rest alone with the electronic supply system. Manufacturers and contractors often indicate incorrect reference numbers. To clarify and adjust such errors, an exact identification of the item referred to is required.

(b) Item and manufacturers' numbers are continually being superseded by new data. This new data may apply to a specific equipment and symbol number, but may not affect other equipments also referenced by the same ESO stock number.

(c) Quite often, due to an oversight, an incorrect manufacturer's reference number may have been overlooked by the screeners at the requisitioning activity. Only the most complete associate descriptive information can make it possible to determine the correct item required.

(d) ESO stock numbers do not reference all shipments to which a specific ESO stock number applies. In this case, the equipment and symbol number are required to verify the application of the ESO numbers to the item requested.

(e) In cases where an ESO stock number is not available, the necessity for this information should be self-evident.

(2) Complete descriptions (ESO item description):

(a) To check information supplied on requisitions against records at ESO.

(b) To determine availability of equivalents at ESO.

(c) To determine necessity for incorporating an item into the stock replenishment program.

(d) To determine the practicability for fabrication (i. e., primarily, mechanical parts).

(e) To verify manufacturer's designation and manufacturer's part covered by this designation.

(3) Necessity for Contractors' and Manufacturers' Reference Numbers:

(a) To assist in determining whether or not the manuacturer's item has been modified by the contractor.

(b) An additional cross-reference for determining accuracy of information.

(c) To notify activities of corrected and superseded contractors' and manufacturers' reference numbers.

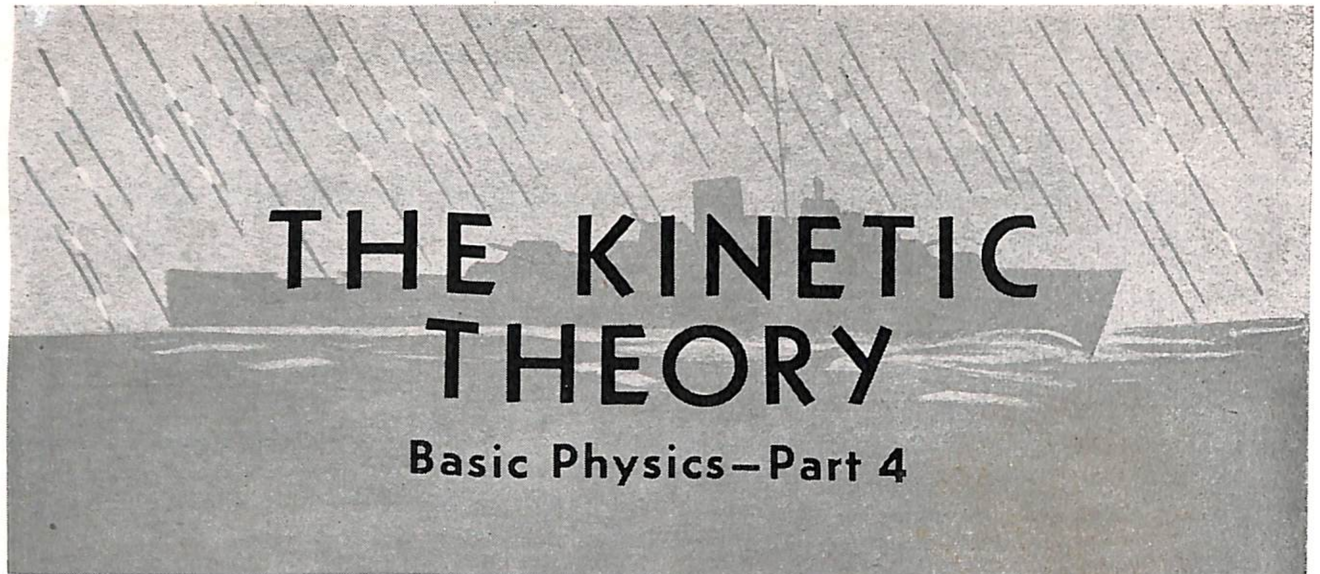
(d) To assist in procurement when the item has not been previously included in the ESO stock numbering system.

Items requested for obsolete equipment will not be supplied. Such obsolete equipments will be listed in Ships 242A or supplementary BuShips publications. Obsolete equipments are completely inactive. Obsolescent material, however, is not inactive, but is material being replaced gradually by some current equipment. When expensive components or items are requested for obsolescent material, it will be suggested to the requisitioning activity that they replace this material with current equipment. Economy is not the only factor to be considered. Manufacturers of obsolescent equipments have stopped supplying the components peculiar to the equipment, and the electronic supply system is then confronted with the problem of procuring assembly drawings and contacting additional commercial organizations for possible manufacture of such items. This causes, in addition to great expense, a considerable production delay which would probably exceed the period of time necessary to replace the entire obsolescent equipment model.

Material requests applying to unauthorized projects not included in the electronic supply system.

Material in classes other than Class 16 is often confused with items carried in the electronic supply system (i. e., many electrical test equipments applied to Class 17). Material should be firmly established as a Class 16 item. [*Class* as herein used bears reference to the Federal Standard Stock Catalog. If in doubt as to the class of a given item, and have no such catalog, consult your Supply Officer—Ed.]

ESO appreciates the questions originating from the various activities and will attempt to clarify such questions in current editions of their "ESO Newsletter." It must be realized that the standardization program, as well as the Electronic Supply Office, is a newly organized phase of the electronic supply system. As ESO matures and develops to its fullest capacity, requisition problems will undoubtedly be clarified with the elimination of continued procurement delays. All activities can assist in meeting this aim by complying with the policies and suggestions herein set forth.



■ The first record of an intelligent hypothesis as to the composition of matter dates back to the fifth century B.C. when Lucretius and Democritus, Greek philosophers, suggested that all matter might be composed of discrete particles of the same elemental substance. Two thousand years later scientists found this concept a powerful tool in explaining the composition and action of matter under varying conditions of temperature and pressure. The kinetic theory extension of this concept offers a logical explanation of such phenomena as the different states of matter (solid, liquid, and gaseous), pressure in gases and liquids, diffusion of gases, change in temperature, and the nature of heat. The theory has been substantiated by such a wealth of experimental evidence that today it is accepted as an established fact rather than as a theory.

The kinetic theory stems from two basic assumptions: a—all matter is composed of discrete particles called molecules; b—at normal temperatures and pressures all molecules are in a constant state of motion or agitation.

A molecule is defined as the smallest particle of matter that retains all the original chemical properties of that matter. If a small drop of water is continuously subdivided, a molecule of water will yield hydrogen and oxygen, two substances that have quite different properties compared to those of water.

A vivid imagination is necessary to visualize matter in terms of particles of extremely small size and mass. It is well to bear in mind that the idea of the size of a given quantity of matter is relative, depending upon the magnitude of the unit of measure. When measured in tons, a given pile of sand might represent only a few units, whereas, when measured in grains of sand, the pile represents a relatively large number.

In this chapter the molecule will appear to be so small as to represent practically negligible size and mass. In a subsequent chapter the size of a molecule will be compared with that of even smaller particles, atoms and electrons. The molecule is a relatively large particle when an electron is used as a unit of measurement. In the study of molecules, atoms and electrons, the fact that size is relative is very important.

The best optical microscopes with magnifications of 10,000 times or more fall far short of making even a giant molecule visible. A minute droplet of oil on a smooth water surface will spread to cover an area such that, if the film is only one molecule thick, the diameter of a molecule must be less than one-millionth inch. The amount of soap solution in a soap bubble suggests a molecular diameter less than one-ten-millionth of an inch. More accurate measurements based upon electrolytic films and the charge of an electron indicate that the molecule has a diameter in the order of 0.00000001 centimeter.

The number of gas molecules in a cubic centimeter of air under normal conditions of temperature and pressure is about 2.7×10^{19}, a number so large it is best approximated by the number of grains of sand that could be packed into one cubic mile of space. In a gas the molecules are widely separated, the average or mean distance between molecules being about a thousand times greater than the spacing between the molecules of a solid. In a cubic centimeter of liquefied oxygen there are about 2×10^{22} molecules, about a thousand times more than are present in a cubic centimeter of oxygen gas under normal conditions. These figures are not particularly important, and are given solely to establish the almost infinitely-small size of an individual molecule and the enormous number that can exist in a small volume of space.

The second assumption upon which the kinetic theory is based has been verified in a number of ways. If a small quantity of aniline dye is dissolved in a suitable liquid and a microscope focused upon an individual dye particle, the particle will be observed performing a series of erratic movements. These movements are exactly the type that would be expected if the particle were being buffeted by rapidly-moving molecular particles. This movement of colloidal particles is called the Brownian movement, after its discoverer, and, when analyzed quantitatively, gives a good approximation of the number of molecules per unit volume, the average distance between molecules, and the average or mean velocity of the molecules. Figure 1 typifies the erratic motion of a colloidal particle in the Brownian movement.

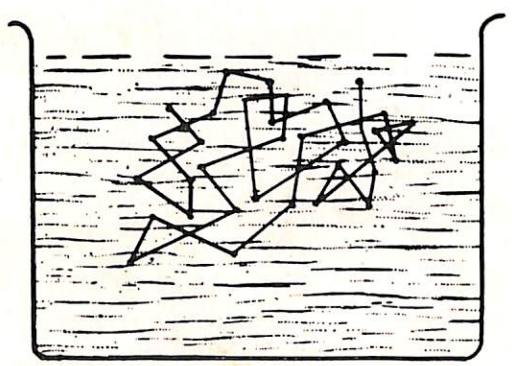


FIGURE 1—*Brownian Movements.*

The velocity of a molecule under normal conditions is primarily a function of temperature. Nitrogen gas molecules at normal pressure and temperature (76 cm of mercury and 0°C) have an average velocity of 1000 to 1300 feet per second, which increases to 1900 to 2300 feet per second at 100°C and the same pressure. Under normal conditions a nitrogen molecule will collide with other molecules about five billion times per second, the number of collisions increasing with temperature.

STATES OF MATTER

Solids. The kinetic theory offers a logical explanation for the existence of matter in any of three states: solid, liquid, or gaseous. A solid is any substance that offers appreciable resistance to forces tending to change its shape or volume. The molecules in a solid are so closely packed that, in all probability, they are almost in direct contact. This close confinement limits the movement of the molecules to a to-and-fro, or vibratory, type of motion. When the temperature of a solid is increased, the vibratory motion of the molecules increases, and the greater force exerted by colliding molecules tends to expand the substance. In most solids volume increases and density decreases with an increase in temperature.

The nature of the cohesive forces that bind molecules together is not yet thoroughly understood. At one time they were thought to be a combination of gravitational and electrical forces, but now they are believed to be primarily electrical forces. The nature of these forces will be explained when the internal structure of the molecule is discussed in a subsequent chapter.

Many of the properties of matter can be explained in terms of the binding force acting between molecules. In a normal solid this force acts to hold a molecule in equilibrium. Matter is elastic because the binding force tends to return the molecules to a position of equilibrium when an external force strains them out of position. When the binding force is incapable of returning all the molecules to their original position, plastic deformation occurs. In a hard material, the binding force is very strong, and it is difficult to change the position of the molecules unless large external forces are applied. In a brittle substance, fracture takes place quickly with little plastic deformation, indicating that the binding force is greater in some directions than in others. Malleable and ductile substances may be thought of as breaking in a series of individual fractures between small groups of molecules, with the molecules finding new positions of equilibrium for each change in dimension of the material.

Most solids and many liquids have their molecules arranged in a regular order like bricks in a wall. Crystal growth suggests that molecules arrange themselves in rank-and-file order much like soldiers in military formation. Each molecule faces in the same direction and is separated from neighboring molecules by a distance determined by the components of the binding force acting upon it from all directions. Practically all metals have this crystalline structure, and it will be shown later that this peculiar arrangement explains why metals are good conductors of electricity.

Some substances, of which glass and rubber are typical examples, have no regular molecular arrangement. They are called amorphous solids to distinguish them from solids exhibiting crystalline structures. A principal characteristic of amorphous solids is that they have no well defined melting point. As glass, for example, is heated, it will gradually soften instead of melting at some fixed temperature.

X-rays have been used to determine the arrangement of the molecules in a large number of substances. The results indicate that the arrangement varies from simple cubes, as in ordinary table salt, to exceedingly complex geometric formations, such as are found in snowflakes. Crystal structure plays an important role in determining the mechanical properties of matter. The many different grades of steel differ primarily in the crystalline arrangement of their molecules.

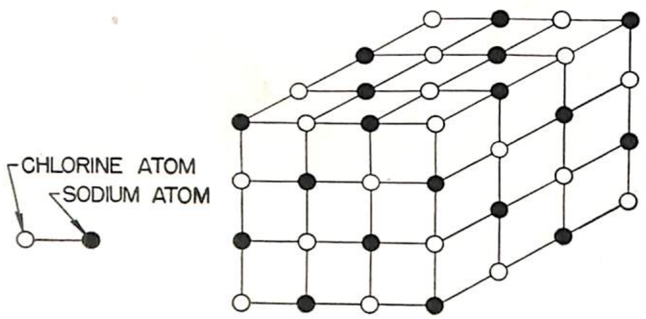


FIGURE 2—*Arrangement of molecules in table salt crystal. Table salt molecule equals sodium atom plus chlorine atom.*

Liquids. A liquid is a substance that offers little opposition to forces tending to change its shape, but strong opposition to forces tending to change its volume. The molecules in a liquid may be likened to a swarm of bees in a hive, continually crawling over, under, and around each other in all directions. Liquids tend to diffuse slowly because it is difficult for an individual molecule to make an appreciable advance in any one direction against the helter-skelter motion of adjacent molecules.

The binding forces acting between liquid molecules are much less than those existing in a solid, but are still appreciably greater than the forces acting between gas molecules at normal pressures. Viscosity is a rough measure of the magnitude of these binding forces. The great variation in freezing and vaporization temperatures of various liquids is indicative that the binding forces may vary over a wide range.

The surface tension of a liquid acts to compress the liquid into a minimum volume of space. It results from the unequal forces acting upon molecules on the surface of a liquid. As shown in figure 3, a molecule within a liquid is acted upon by forces from all directions; these forces tend to counterbalance each other. A molecule at the surface, however, is not subject to a binding force from above, hence the downward components of binding force tend to exert an elastic force to minimize the volume of the liquid.

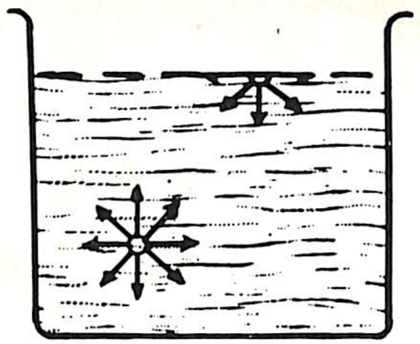


FIGURE 3—*Surface tension of a liquid results from uncancelled molecule forces at the surface.*

A molecule of a liquid is capable of three types of motion: translational or point-to-point movement, vibrational or to-and-fro movement, and rotational or circular movement. In all probability, a molecule of a liquid undergoes all three types of motion simultaneously. Highly volatile liquids (which evaporate rapidly at normal temperatures) have molecules with high translational velocity. A viscous liquid like a heavy oil is probably made up of molecules with high vibrational velocities. Such properties as fluidity and oiliness are functions of the spinning motion of the molecules.

Pressures in Liquids. A liquid offers strong opposition to forces tending to change its volume.

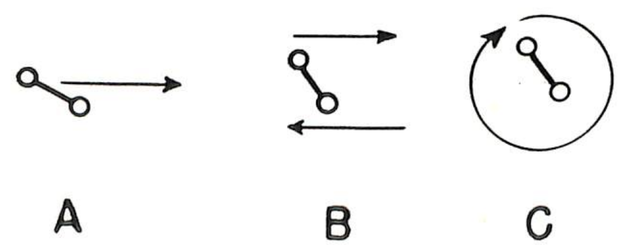


FIGURE 4—*Three possible types of motion of a molecule: (A) translational, (B) vibrational, and (C) rotational. Combinations of any or all of these types are also common.*

This fact is of primary importance in hydraulics, for it indicates a liquid is an efficient medium for transmitting a force.

There are two pressures to consider when investigating the nature of pressures in liquids: the pressure exerted by the liquid upon the container in which it is confined and the pressure acting at various points within the liquid. Molecules possess weight by virtue of their mass, and hence are acted upon by the force of gravity. The resulting pressure exerted by water upon the bottom of a tank varies directly as the volume of water in the tank. Consider a tank with a bottom cross-section of one square foot. Since one cubic foot of water weighs 62 pounds, the volume of water exerts a pressure of 62 lb/ft^2 on the bottom of the tank. Two cubic feet of water will exert a pressure on the bottom of the tank of 124 lb/ft^2, three cubic feet 186 lb/ft^2, etc. At an oceanic depth of one mile, the pressure is more than 160 tons per square foot. The downward pressure exerted by a liquid increases directly as the depth.

Consider now the pressure exerted at various points within a liquid. The statement that the pressure is the same in all directions within a liquid does not seem to agree with the increase in pressure with depth. What is meant is that, if the pressure is measured at any selected point within the liquid, no matter in what direction the pressure force is measured, it will be the same at least for a liquid of the same temperature throughout. If this were not true, a movement of the liquid would take place in the direction of the least pressure. In figure 5 is shown a rectangular tank with a bottom area of one square foot. The downward pressure of the weight of the water varies from zero at the surface to maximum at the bottom of the tank. However, note that

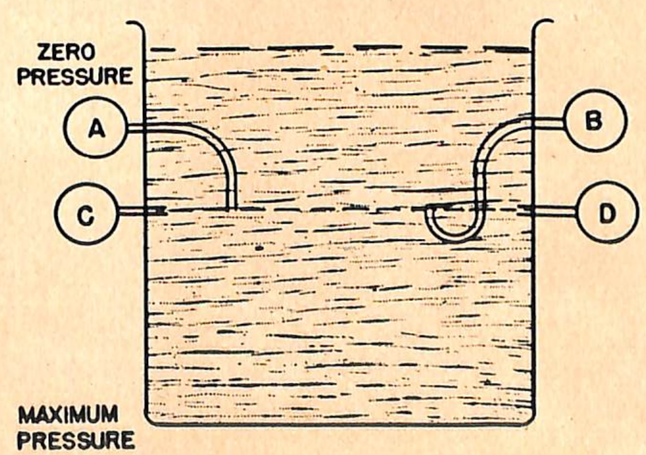


FIGURE 5—*Pressure acting on a molecule of a liquid of uniform temperature is the same in any direction.*

pressure gauge A reads the pressure acting upward in the middle of the tank, gauge B the pressure acting downward, gauges C and D the horizontal pressure in opposite directions. All gauges read the same value, indicating that the pressure acting on any given molecule in the liquid is the same if the temperature of the liquid is uniform throughout.

However, movement in the direction of least pressure often occurs when the temperature of the liquid is not uniform. In the gravity type hot water heating system, the boiler is placed at a lower level than the radiators. The water in the radiators is cooled by radiation, which causes it to contract slightly, increasing the density (weight per unit volume). The greater weight of the cooler water forces the hot water in the boiler to move upward toward the radiators, while the cooler water returns to the boiler for reheating.

Gases. A gas is defined as a substance which, at normal pressures and temperatures, offers very little opposition to forces tending to change either the shape or volume. The binding forces between gas molecules at normal pressures are so small that, for all practical purposes, the molecules may be assumed to be free to move in any direction at any time. The small value of these forces is a direct result of the wide spacing between gas molecules at normal temperatures and pressures. An "ideal gas" is one in which the cohesive forces can be assumed to be zero. Such an assumption makes it somewhat easier to analyze gases in terms of the kinetic theory. However, compressing a gas reduces the distance between molecules, and at very high pressures the cohesive forces can no longer be considered negligible. In fact, if a gas is sufficiently compressed and cooled, it will liquefy, and if the process is carried still further, it will eventually solidify. The dry ice of commerce is solidified carbon dioxide, which gradually returns to the gaseous state as heat is absorbed from the surrounding atmosphere.

In a gas, at any given instant of time, there will be a few molecules moving at very high velocities and a few at very low velocities. A disproportionately great number will be moving at velocities lying between these extremes. The mean or average velocity of the molecules is primarily a function of temperature. Although it is conceivable that a gas molecule might be brought to rest by a series of head-on collisions, it would remain in such a state only for an instant before other collisions set it in motion again. The idea of an average or mean velocity of the gas molecules is important in considering the action of a gas under different conditions of temperature and pressure.

A second important factor in the action of a gas is the mean-free-path between molecules. If in a given volume of gas under constant pressure, all the molecules were evenly spaced throughout the container, the distance between molecules would be equal to the mean-free-path—the average distance which a moving molecule could traverse before colliding with another molecule. The mean-free-path is primarily a function of pressure, the length of the path decreasing as the gas is compressed into a smaller volume. The mean-free-path of the molecules in a gas is a thousand or more times greater than in a liquid or a solid. Because of this, molecules can accelerate to velocities in the order of several thousand feet per second before colliding with another molecule.

Since

$$KE = \frac{mv^2}{2},$$

even though the mass of an individual molecule may be very small, it can store up considerable kinetic energy by virtue of the high velocity attained over a long free-path. The ability of a gas to expand rapidly and to generate large forces of expansion (such as occur in an explosion) is a direct result of the high molecular velocities. The long free-path and high molecular velocity also explain why a gas may diffuse rapidly. Brownian movements are greatly exaggerated in a gas, causing rapid intermingling of the molecules when two or more gases are mixed.

Gases have little weight because of their low densities (accounted for by the wide spacing between individual molecules). As a gas is compressed, the density increases, but the weight remains constant. Compression decreases the spacing between molecules but does not affect the total number of molecules in the gas.

Gas pressure is the effect produced by myriads of high-velocity molecules beating against the walls of the container. Our crude senses and instruments measure the millions of individual collisions as a continuous force or pressure.

The kinetic theory encountered many stumbling blocks before it was realized that gas molecules were capable of the three previously-mentioned types of motion: translational, vibrational, and rotational. Because of the freedom of movement of individual gas molecules at normal pressures, it is possible for the molecule to shift from one type of motion to another very quickly. Normally, gas molecules will have components of all three types of motions, and the magnitude of each component will vary continuously. It should be evident that gas pressure is primarily a function of translational motion.

The Fundamental Gas Laws. If the temperature of a gas is maintained constant, the mean velocity of the molecules will be constant. Under these conditions, if a gas is compressed into a smaller volume, a greater number of molecules will strike per unit area of the container, and the pressure increases. The relation between volume and pressure for an ideal gas is given by Boyle's law, which states that, if the temperature is constant, the gas pressure will vary inversely as the volume, or

$$\text{Pressure} \times \text{volume} = \text{a constant.}$$

Expressed in another way:

$$\text{Initial pressure} \times \text{initial volume} = \text{final pressure} \times \text{final volume}$$

$$P_iV_i = P_fV_f \text{ (if temperature is constant)}$$

Boyle's law does not hold true at pressures where the cohesive forces between molecules become appreciable.

A second gas law is important because it offers a quantitative definition of temperature. The kinetic energy of a gas molecule is

$$KE = \frac{mv^2}{2}$$

If m is the mass and v the average velocity of all the molecules, then the quantity $\frac{mv^2}{2}$ is called the *temperature of the gas.*

The second law states that if the volume of a gas is constant, the pressure will vary directly as the *absolute temperature;*

$$\frac{\text{initial pressure}}{\text{final pressure}} = \frac{\text{initial temperature}}{\text{final temperature}}$$

$$\frac{P_i}{P_f} = \frac{T_i}{T_f} \text{ (if volume is constant)}$$

The reason underlying this law is simple. If $\frac{mv^2}{2}$ defines the temperature of the gas and the mass of a molecule is constant, then temperature must vary directly as velocity or, stated another way, velocity varies directly as the temperature. As we know, pressure is a measure of the force of impact of molecules colliding with the walls of the container and this force will vary directly with the velocity and hence with the temperature of the gas.

A third law of gases concerns the variation of volume with temperature when the pressure is constant:

$$\frac{\text{initial volume}}{\text{final volume}} = \frac{\text{initial temperature}}{\text{final temperature}}$$

$$\frac{V_i}{V_f} = \frac{T_i}{T_f} \text{ (if pressure is constant)}$$

This law indicates that volume must vary directly as the temperature for constant pressure. As the temperature of a gas increases, the molecular velocity increases, tending to increase the pressure. By increasing the volume of space in which the gas is confined, this increase in pressure can be counteracted.

If the volume of gas is held constant, an increase in temperature of 1°C will cause the pressure to increase by an amount equal to $\frac{1}{273}$ of the pressure at 0°C. Similarly, if the pressure is held constant, a temperature increase of 1°C will increase the volume by an amount equal to $\frac{1}{273}$ of the volume at 0°C. The constant $\frac{1}{273}$ (as a decimal 0.00366) is called the pressure-volume coefficient of an ideal gas. The origin of the number 273 will be evident when absolute zero is investigated.

Absolute Zero. Since temperature is a measure of the mean velocity of the molecules, and this velocity decreases as a body is cooled, there should be a temperature at which the molecules are at rest. This temperature exists, and is called "absolute zero." A body at absolute zero temperature would be devoid of all kinetic energy. It should be evident that absolute zero temperature would be a difficult value to measure with any man-made temperature measuring device. Indirect measures must be resorted to to find the temperature in degrees Centigrade corresponding to absolute zero. The method by which this value may be determined will be described here because it represents a dodge often used in electronics work to find a value that cannot be measured directly.

Into an evacuated metal cylinder equipped with a pressure gauge sufficient helium gas is introduced so that, when the cylinder is packed in cracked ice (0°C), the pressure gauge reads normal atmospheric pressure (14.7 lb/in²). If the cylinder is now packed for a time in dry ice, the temperature will be lowered to −78°C, the melting point of carbon dioxide. At this temperature the pressure gauge will read 10.5 lb/in². The pressure at 0°C and that at −78°C are all that is needed to determine absolute zero because two points determine the position or location of a straight line. However, as a check, an additional point should be determined. If the cylinder is immersed in liquid nitrogen, the temperature will drop to −196°C, and the pressure to 4.14 lb/in². By collecting the measured results the following table may be constructed:

Temperature in °C	*Pressure in lb/in²*
0	14.7
−78	10.5
−196	4.14

These values are plotted in figure 6. Since pressure varies directly with temperature, when the volume is constant, the plotted curve will be a straight line. Extending the curve to the point where it intersects the temperature axis—at which point the pressure is zero, indicating zero molecular velocity—will enable the value of absolute zero to be read. It is about −273°C, more accurately −273.18°C. Helium gas was selected for the

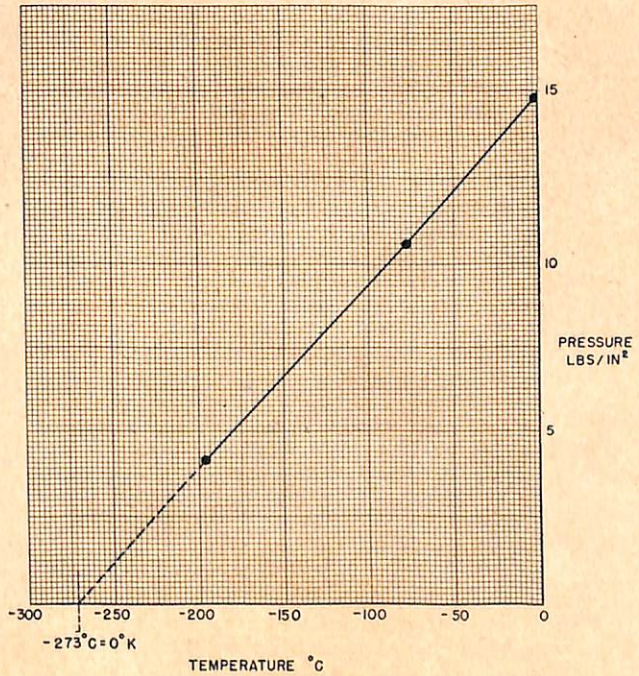


FIGURE 6—*Experimental determination of absolute zero temperature.*

experiment because it liquefies at −268.9°C and solidifies at −272.2°C. In laboratory experimental work, temperatures slightly lower than −273° have actually been attained.

THE NATURE OF HEAT

The electronics engineer has a primary interest in heat energy, because the capacity of electrical and electronic devices to accomplish work is invariably limited by the heat energy developed in converting energy from one form to another. The preceding discussion of gases was intended to precondition the student for instruction in heat energy concepts.

Since supplying heat to a gas increases the temperature of the gas by increasing the kinetic energy of the molecules, it is a reasonable assumption that heat energy is precisely this energy of motion. It would appear that a given quantity of heat energy should affect equal volumes of different gases in the same way, but experimental results do not support this theory. The quantity of heat required to raise the temperature of a one-gram mass of gaseous carbon dioxide 50°C will only increase the temperature of an equal mass of hydrogen gas 3°C. Eventually the conclusion was reached that the heat energy could be absorbed by a gas in three ways: a—by increasing the translational motion of the molecules, b—by setting one part of a molecule into vibration with respect to another, much in the way that a small section of a spring will vibrate while other portions remain at rest, and c—by increasing the rotational velocity of the molecules. It is the translational motion of the molecules that determines their mean velocity, and hence their temperature. In the above example, more heat energy is converted to translational velocity in the case of carbon dioxide than occurs with hydrogen; hence a given quantity of heat will cause a greater rise in the temperature of the carbon dioxide.

A point that often confuses the student, and one that many elementary texts fail to clarify, is the reason why the moving molecules do not eventually come to rest of their own accord. Moving bodies in our everyday world are always brought to rest by frictional forces unless energy is supplied to overcome such forces. Friction does not act to decrease the velocity of the molecules because no overall energy conversion takes place. The kinetic energy of the moving molecules is heat energy to begin with. Friction between molecules can produce only heat energy, so no energy conversion takes place. Therefore, the velocity of the molecules is maintained in accordance with Newton's first law of motion, because there is no external force accomplishing work against the molecules.

MEASUREMENT OF HEAT

It should be evident that the average velocity, that is the temperature, of a group of molecules is independent of the number of molecules. A group of ten million molecules can have the same average velocity as a larger or smaller number. Therefore, temperature cannot be taken as a measure of the quantity of heat energy. A quart and a pint of water may have the same temperature, and hence the same average molecular velocity, but to raise the temperature of the quart of water 1°C would require more heat energy—in fact twice as much—as that required to raise the temperature of the pint the same amount. That the quantity of heat energy is a function of both the quantity of matter and the average velocity of the molecules is evident from

$$KE = \frac{mv^2}{2}$$

which defines heat energy as the average kinetic energy of all the molecules. A unit of heat energy involves both temperature and mass.

The two units of heat energy in common use are the calorie and the British Thermal Unit (BTU). The calorie, a C.G.S. unit, is that quantity of heat required to raise the temperature of one gram (one cubic centimeter) of water 1°C. The appropriate M.K.S. unit is the kilocalorie, equal to 1000 calories. The British Thermal Unit, an F.P.S. unit, is the quantity of heat required to raise the temperature of one pound of water 1°F. Can you demonstrate that one BTU is equivalent to 252 calories?

The quantity of heat required to raise the temperature of a given mass of water 1°C varies with the initial temperature of the water. The mean calorie is defined as one one-hundredth of the heat required to raise the temperature of one gram of water from 0° to 100°C. The mean calorie is found to be equal to that heat required to raise the temperature of one gram of water from 15 to 16°C and the calorie is often defined at that point on the temperature scale.

Mechanical Equivalent of Heat. In the course of several years of investigation James Joule of England demonstrated that no matter how mechanical energy is converted to heat energy by rotating paddles in a liquid, by forcing liquids through pipes, by friction between rubbing surfaces, etc., the ratio of mechanical energy input to heat energy output was always the same. Precise measurements indicate that 4.186 joules of mechanical energy is equal to one calorie of heat energy. The constant 4.186 is called the mechanical equivalent of heat, and represents the number of units of mechanical work that must be accomplished to generate one unit of heat energy.

$$1 \text{ calorie} = 4.186 \text{ joules}$$

With this relationship it is possible to evaluate electrical and mechanical energy in terms of heat energy. For example a kilogram (about 2.2 lb) of water elevated against the force of gravity through a distance of 1480 feet represents the mechanical work which, if converted to heat energy, would raise one kilogram (about a quart) of water 1°C. This is indicative of the tremendous quantity of heat energy that may be stored in a small quantity of water.

Temperature Measurement. Temperatures of interest to science range from absolute zero to thousands of degrees Centigrade. Temperature-measuring devices, however, are capable of measuring only a limited portion of this total range. The design of such devices is strongly influenced by the range of temperatures to be measured, as well as the point in the temperature scale where measurement is desired.

Practically any physical phenomenon that varies with temperature may be used as the principle of a temperature-measuring device. Such devices are usually called thermometers or pyrometers. A regulating device designed to measure temperature in equipment and to help maintain it at a predetermined temperature is called a thermostat. The mercury thermometer is a familiar device. Since mercury freezes at −39°C and boils at 357°C, the mercury thermometer is limited to temperature measurements within these limits. Ethyl alcohol, which freezes at −130°C and boils at 78°C, is often used as a substitute for mercury when it is necessary to measure temperatures below the lower limits of the mercury thermometer.

The principle of unequal expansion in a bimetallic strip is of interest because bimetallic thermostats are often used in temperature-regulated electronic equipment. The basic principle of the thermostat is the difference in expansion with temperature of two dissimilar metals. Copper has a linear coefficient of expansion about sixteen times greater than invar, an alloy of 64% iron and 36% nickel. If a strip of copper is securely riveted to a similar strip of invar at some reference temperature, 0°C, for example, then an increase in temperature above this level will cause the copper to expand more than the invar. This will force the strip to warp or bend in the direction of the invar. A decrease in temperature below the reference level will cause the strip to bend toward the copper. By rigidly clamping one end of the strip, the movement of the free end, through a suitable mechanical amplifying mechanism, can be used to operate an indicating device. Although the bimetallic thermometer is not as sensitive as the mercury or alcohol type, it possesses great ruggedness, and hence finds wide application in industry.

There are various other methods of measuring temperature. The resistance-type thermometer functions on the basis of the variation of resistance with temperature. The thermocouple thermometer functions on the principle that, if the junction of two dissimilar metals is heated, a difference of potential or electromotive force will be established across the junction. A series of thermocouples so arranged that the generated electromotive forces are additive is called a thermopile. Such an instrument may be used to measure temperature changes of less than one ten-millionth of a degree. The optical pyrometer, a device for measuring high temperatures, compares the color of a heated filament with that of a high-temperature body. The color of the heated filament may be controlled by varying the electric current used to heat it. When the two colors agree, the filament and glowing body are at the same temperature. The temperature of the filament is then determined from a temperature calibration chart.

Temperature Scales. The Centigrade scale is considered a part of the metric system, and is used

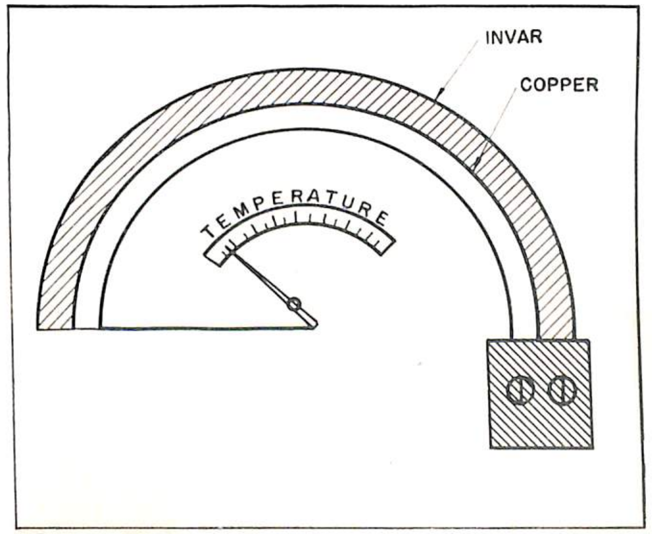


FIGURE 7—*Principle of bimetallic thermometer.*

in most scientific work. The Fahrenheit scale, commonly used in the United States and Great Britain, may be considered as the standard temperature scale of the F.P.S. system. The Kelvin or absolute temperature scale is used mostly in work with gases.

The student should be familiar with the methods of converting from one temperature scale to another. There is no necessity for memorizing temperature conversion formulas if a few basic facts concerning the different scales are memorized. Zero degree Kelvin corresponds to –273°C, so conversion from °C to °K is accomplished by simply adding 273 degrees to the given Centigrade temperature. Similarly, °C = °K – 273.

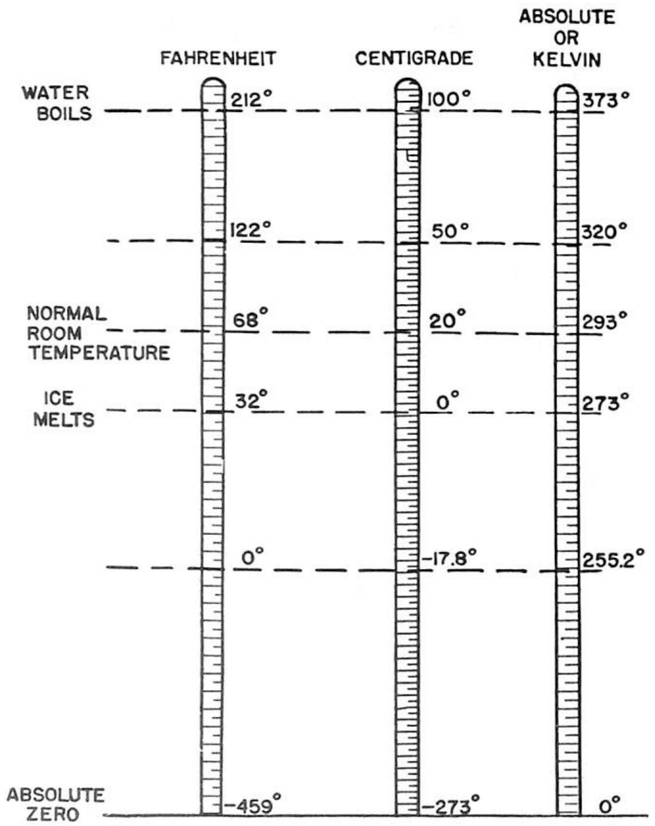


FIGURE 8—*Comparison of temperature scales.*

The melting and boiling points of water at normal pressure are the basic calibration points of the Centigrade and Fahrenheit scales. Ice melts at 0°C or 32°F, and water boils at 100°C or 212°F. Between melting and boiling point, the *change* in temperature is 100°C or 180°F, hence an increase in temperature of 1°C is equivalent to an increase of $\frac{180}{100}$ or 1.8°F. Keep in mind that 1°C change in temperature = 1.8°F change in temperature. For example, the problem is given of converting 60°C to °F. To increase water from 0°C to 60°C involves a change of 60°C, which corresponds to an increase of 60 × 1.8 or 108°F above the melting point of water. Since 32°F is the melting point of water, a change of 108° above this point represents a temperature of 32 + 108 or 140°F. Therefore 60°C = 140°F. A second example: Required to convert 36°F to °C. A temperature of 86°F is 86 – 32 or 54°F above the melting point of water. A change of 54°F corresponds to a change of $\frac{54}{1.8}$ or 30°C, hence 86°F = 30°C.

EXERCISES, PART 4

1. At what depth in feet below the surface of the sea will water pressure equal normal atmospheric pressure? Density of sea water is 64.2 lb/ft³.

2. A vacuum pump reduces the pressure in a vacuum tube from normal atmospheric pressure to 0.001 millimeters of mercury. What pressure in pounds per square inch does this degree of vacuum represent?

3. What is the maximum temperature range of mercurial type Fahrenheit thermometers?

4. Rubber covered wire should not be subjected to temperatures in excess of 50°C if rapid deterioration of insulation is to be avoided. What does this temperature correspond to in °F?

5. At what temperature will a Fahrenheit and a Centigrade thermometer have the same numerical reading?

6. A tank ten feet deep is filled with fresh water. At what depth will the pressure be 3.5 lb/in²?

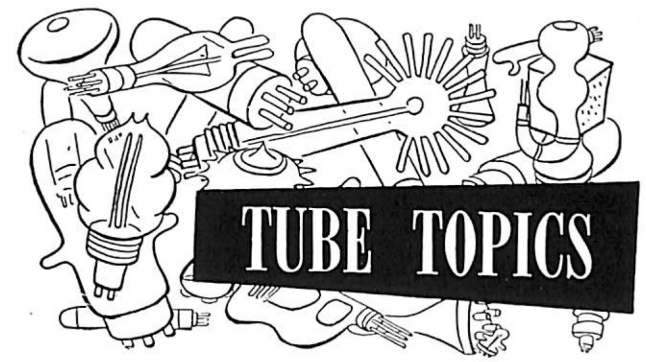
7. If a fixed volume of gas exerts a pressure of 10 lb/in² at 68°F, at what temperature in °C will the pressure be 20 lb/in²?

8. How many foot-pounds of work are equivalent to one British Thermal Unit?

9. A motor delivers 10 hp for 8 hours. If the motor is 85% efficient, how much energy in kcal is wasted as heat during the operating period?

ANSWERS TO EXERCISES, PART 3

(1) 1,230,000 ft³.
(2) 362 lbs.
(3) 10.5 lb/in².
(4) 0.8 gm/cm³.
(5) 1130 short tons/ft², or 1000 long tons/ft².
(6) 4.78 cm.



OBSOLETE TUBES

JAN specifications for the tube types listed below have been cancelled by the Joint Army-Navy Tube Committee as the greater majority have become obsolete and are no longer available.

OZ4	1F4	2E5	31
O1A	1F5G	2V3G	49
1B4P	1H4G	*6AHGT	70L7GT
1C6	1H6G	**6B6G	79
1C7G	1J6G	6C7	††83V
1D5GP	1J6GX	†6V7G	89Y
1D7G	2A4G	6Y7G	117Z4GT
1D8GT	2A5	6Z7G	‡‡6F6G
1E5GP	2A6‡	‡12A/112A	6U6GT
1E7G	2B7‡	12A5	

* Interchangeable with adapter for 6F8C or 6SN7GT.
** Interchangeable with adapter for 6T7G or 6Q7GT.
† Interchangeable with adapter for 85.
†† Interchangeable with adapter for 5V4G.
‡ Directly interchangeable for 71A.
‡‡ Directly interchangeable for 6F6GT.

A few of these types are being constructed in limited quantities for special applications but will no longer be available for general use. It is suggested that equipments utilizing these types of tubes be declared obsolete where practical, that is, where no JAN interchangeable tubes exist or where it is not feasible to adapt the circuits to utilize the present JAN type tubes.

In general, equipments utilizing these types of tubes are very old and have already been declared obsolete but, as is indicated by purchase requests received by the Bureau, they are in a few cases still being used. Electronic equipments other than the established navy types which use these tubes must either be declared obsolete or be modified to use JAN type tubes.

WATCH THAT OVERLOAD SWITCH

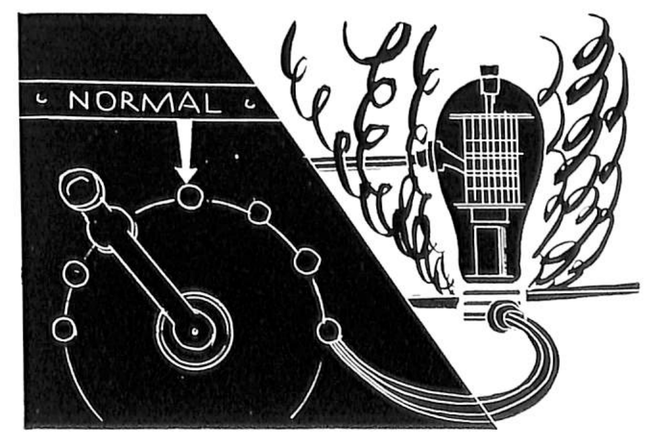
A large percentage of the failures in our electronic equipments can be traced to overloads which occur in the circuits and remain undetected. A very good example is a recent trouble which occurred in the SP Radar.

Selenium rectifiers, CR-3210 and CR-3211 and transformer T-3210 which supply field voltage to the training motor shorted out. The trouble was not detected, and after a period of time the dynamo amplifier which was overloaded due to the trouble caught fire and was damaged. Possibly this trouble could have been avoided, especially since the equipment is provided with a safety device designed to eliminate this type of trouble.

In the Power Control Unit, Navy Type CG-23AEM, a unit of the SP console, there is an overload selector switch which affords a method of overload selection when trouble is indicated by the overload indicator lamp, I-1415. This selector switch is of the rotary type having twelve positions, two functioning as NORMAL positions, nine used to indicate overloads at nine different points in the radar system, and the remaining one used to indicate the position of the antenna safety switch (open or closed). With this switch in the NORMAL position an overload on any of the nine circuits will be indicated by the lamp. The location of the overload may then be determined by rotating the switch until the indicator lamp again lights.

This switch and the associated indicator circuits were designed for the specific purpose of forestalling overload troubles and are capable of doing this job if given the chance. Remember this switch and lamp and save yourself a lot of trouble.

CAUTION: THE OVERLOAD SELECTOR SWITCH MUST ALWAYS BE KEPT IN THE NORMAL POSITION EXCEPT WHEN DETERMINING A SPECIFIC OVERLOAD.



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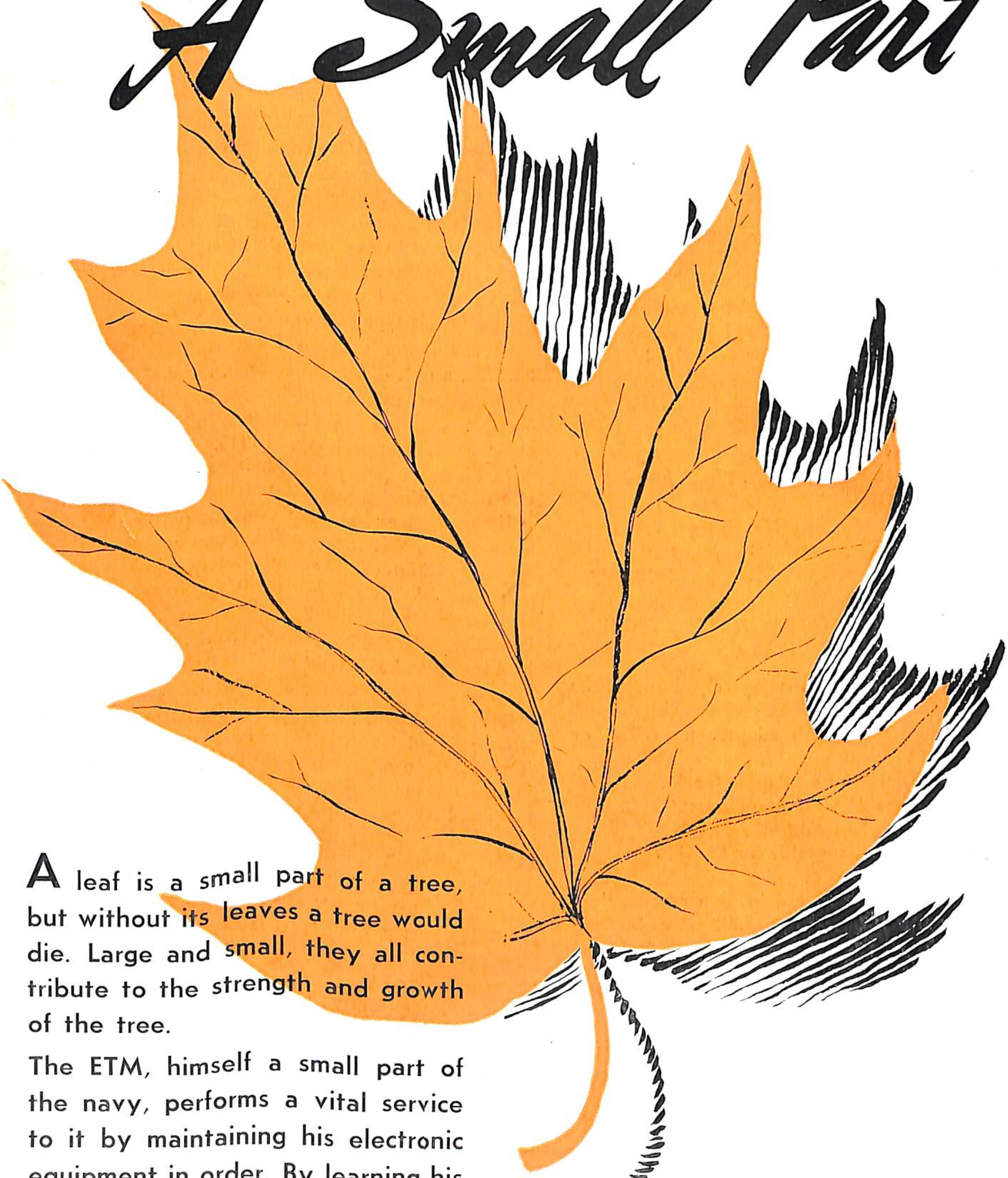
A Small Part



A leaf is a small part of a tree, but without its leaves a tree would die. Large and small, they all contribute to the strength and growth of the tree.

The ETM, himself a small part of the navy, performs a vital service to it by maintaining his electronic equipment in order. By learning his equipment and doing his job well, he adds substantially to the strength and efficiency of this fighting force.