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TRANSMISSION CHARACTERISTICS OF THE NEW TELEPHONE SET

W. C. Jones

At the last conference we talked about transmitters, receivers, head sets, microphonic materials, etc , and built our story for the most part around the 302 type of telephone set.

Since that meeting, the new combined set, the 500 type, has been announced in the press. You no doubt saw the announcements. You also may have seen some of the sets. Today we will build our discussion around the new set. We feel that the new set is one of the things that you will want to show and talk about, and that you will be asked many questions about it.

I am going to talk about the instruments and the transmission characteristics of the set. Bill Tuffnell, whom most of you know, will discuss the set and its components.

We will endeavor to allow adequate time for questions and answers. That part of the presentation is important, because many of your questions will be the same questions that the people in your audiences will ask. We will endeavor, in our talks, to answer the questions which we have been asked and which we feel will ultimately come to you. However, other questions, no doubt, will occur to you.

Any development program, obviously, starts with the outlining of a set of steering directions. When we undertook the development of the new 500-type set, we looked over the plant requirements and user needs, and set up a list of objectives. Those objectives covered a wide range of characteristics, and for the most part have been embodied in the set as we have it. One of the most important performance objectives was improved transmission.

This improvement in transmission called, broadly, for two things: first, an increase of five decibels in

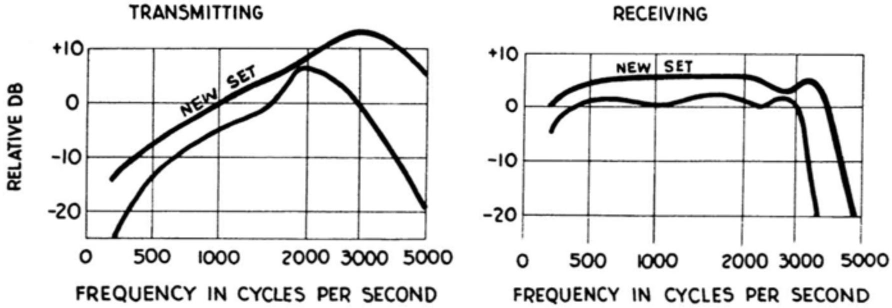

Fig. 1 - Response of the New Telephone Set

transmitting efficiency and an increase of five decibels in receiving efficiency; and second, improvements in the response characteristics of both instruments.

The first chart that I would like to show you develops that picture in more detail. (See Fig. 1). Let us examine the transmitter first. The present transmitter has a rising characteristic, reaching a maximum in the region of 2,000 cycles per second. The response objective for the new transmitter also calls for a rising characteristic, but generally higher by the 5 db that I previously mentioned. It also calls for filling in the upper frequency region.

In these days of instruments with flat response, you might ask, "Why make the response peaked and sloped?" There are two reasons for the deliberate choice of this shape of characteristic. As you will recall, circuit losses increase with frequency. Therefore, since we slope the characteristic upward, we get a compensating effect in this upper-frequency region for the circuit losses.

When we fill in the frequency characteristic so that it reaches its maximum at a higher frequency than in the present instrument, we approach more nearly what we call orthotelephonic transmission, or one-meter speech. This is a rather high-sounding term, but it means this:

The natural reference base line for judging quality, seemed to be the quality which results when two people talk across a desk. That is what we call one-meter speech. Now, if we make measurements of the fundamental characteristics of one-meter speech or orthotelephonic transmission, we find that the basic characteristic peaks in this fashion. So in choosing this transmitting characteristic, we accomplish two things: we offset the circuit losses and provide more nearly one-meter speech.

In the case of the receiver, we not only lift the level 5 db, but we also extend the frequency range by a substantial amount at the high end. The reference line on this chart is the response characteristic of the HA1 receiver of the present 302-type set. It should be borne in mind that this was the first time that receivers having flat response characteristics had been introduced in the telephone plant. Up to that time, the response had been characterized by sharp peaks. That in itself was a substantial contribution to transmission improvement. As you know, these receivers are used in large quantities at the present time.

When we designed the HA1 receiver, we weren't able to extend the frequency range as far as we would have liked. It falls off rather rapidly in the region of about 2,700 cycles per second. We couldn't extend it at that time without sacrificing other important characteristics. But when we set up the objectives for the new set, we included not only an increase in efficiency level but an extension of the range so that we could take full advantage of a 4,000-cycle carrier channel. In other words, if we extended the response to 4,000 cycles, we would be able to use a carrier channel completely without spilling over into an adjacent channel and causing interference.

Before we go on to a discussion of how these objectives were attained, I want to point out something else. We couldn't utilize this increase in efficiency without doing two other things. First, we had to provide means for controlling side-tone; otherwise the higher side-tone volume would cause the speaker to lower his voice, and we wouldn't realize the objectives. Second, an increase of level of 10 db in transmitter plus receiver on short connections such as are obtained in the PBX in this building, would be intolerable. We now have sufficiently good transmission on short connections, but we need the higher efficiency on long connections. Hence, as part of this development, we have built into the set an equalizer that reduces the receiving level and the transmitting level to essentially that of the present set on short connections, but makes the higher levels available on long connections. At the same time it holds the side-tone to the present level on short connections.

Inasmuch as this is a circuit element and a part of the set, Bill Tuffnell will bring out how these results are accomplished. The point I want to drive home at the start is that this program is aimed at providing better transmission on the limiting circuits. By providing better transmission on these circuits and holding that on the short connections to essentially the present levels, a substantial improvement from the standpoint of equalization of transmission with loop length is obtained.

With that introduction let's look at what we have done. First, in the transmitter (Fig. 2); second, in the receiver (Fig. 3).

In order to meet the objective of increased transmitter output, the first thing that we had to do was to build a transmitter that has greater modulating efficiency. The present F-type transmitter is so efficient that you couldn't increase its efficiency by 5 db without getting into difficulty from overloading when a person talks loudly. We elected to increase the transmitter efficiency 2 to 3 db and pick up the remaining 2 to 3 db in the handset, a feature

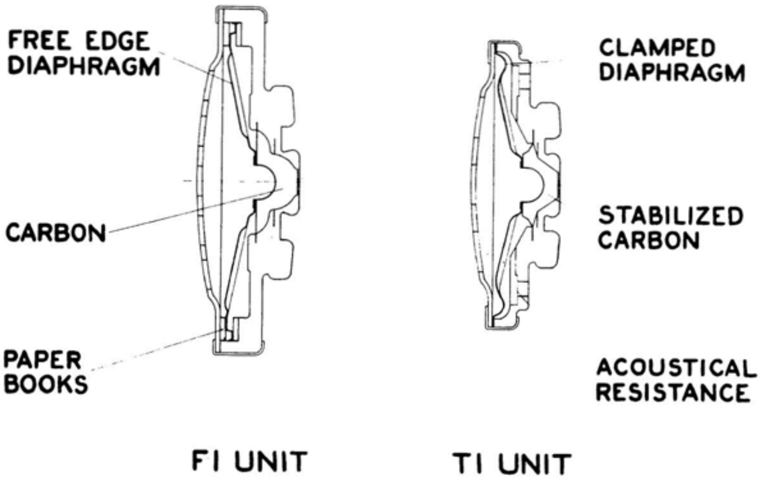

Fig. 2 - The Transmitter

which I will come to later. In other words, one of the first things we did was to design a structure 2 to 3 db more efficient. Right here the interrelation of requirements and objectives came into play, for if it were not for the equalizer, we wouldn't have had the freedom in design necessary to obtain the increased efficiency without getting in difficulty in other respects.

I mentioned the change in the response characteristics, i.e., the rising characteristic and the filling-in of the high end to obtain one-meter speech. Meeting these objectives calls for basic changes in transmitter design. In the old F-type transmitter, the edge of the diaphragm is freely supported between paper books; in other words, it was free to move at an edge, relative to the supporting structure. Now, we couldn't fill in the upper end of the response characteristic by using the freely supported structure. So we adopted a type of construction involving a clamped diaphragm. The introduction of a clamped diaphragm made it necessary to add resistance or damping in order to control the diaphragm response. This was done by venting the cavity in back of the diaphragm through openings in the frame which were covered with resistance material. In other words, we took the damping out of the paper rim support and put it in an acoustic element in the back of the instrument.

The other point which I want to make in connection with this chart is the matter of aging.

When we were together the last time and talked about the present transmitter, we pointed out some of the things that we had done to reduce the mechanical aging of carbon that comes about when the handset is dropped on the mounting. We also told you about some work we were doing with synthetic microphonic materials. The work on the synthetics didn't come along quite as rapidly as we had hoped it would, so that in getting the new set underway, we weren't able to use the synthetics. However, we did make a very marked improvement in the microphonic materials made from anthracite coal by introducing a step in the process to stabilize the material. This change in process results in what we refer to as "stabilized" carbon, which is very much better from the standpoint of aging than the carbon previously used.

By using this stabilized carbon in the new instrument, we have much greater freedom in choosing the resistance of the transmitter. For example, the initial resistance can be made higher because it is not necessary to figure on an increase in resistance during the life of th instrument. This is an important factor because the principal reason for changing instruments in the field at the present time is change in carbon resistance. The increase in resistance often is high enough to make supervision in PBX circuits difficult.

Another factor in the design of the transmitter, which is important, is a reduction in weight. The present handset weighs about 16.5 ounces. In our development we set a bogie of 10 ounces for the new handset. We actually realized 12 ounces, a reduction of about 25 per cent in weight. The reduction in size and weight runs all through the program. These sketches (Fig. 2) give some indication of the reduction in the size of the transmitter unit. Along with the reduction in size there is a substantial reduction in weight.

I will pass around a couple of the transmitter units, one of the old type and one of the new. By comparison you can see rather clearly the differences in external construction and get an idea of the reduction in size and weight.

So much for the transmitter, and what we have done in order to meet the objectives set for it.

In the new handset we are introducing what we call "the ring-armature" receiver. (See Fig. 3.) It represents a major break in receiver design.

Throughout the period following the introduction of the telephone, receivers have, without exception, involved the use of a disc-type diaphragm of iron or magnetic alloy, a pair of pole pieces with coils on them, and a magnet which sets up a polarized field in the gap between the pole pieces and the diaphragm. The polarized field exerts a force on the diaphragm. By passing the voice currents through the coils on the pole pieces, the force on the diaphragm is varied, causing the diaphragm to vibrate and give off sound which is a fairly faithful reproduction of the speech currents entering the receiver. When we set out to raise the receiver efficiency level 5 db and at the same time extend the frequency range, we wiped out the possibility of using this construction. One reason is the high effective mass of the diaphragm.

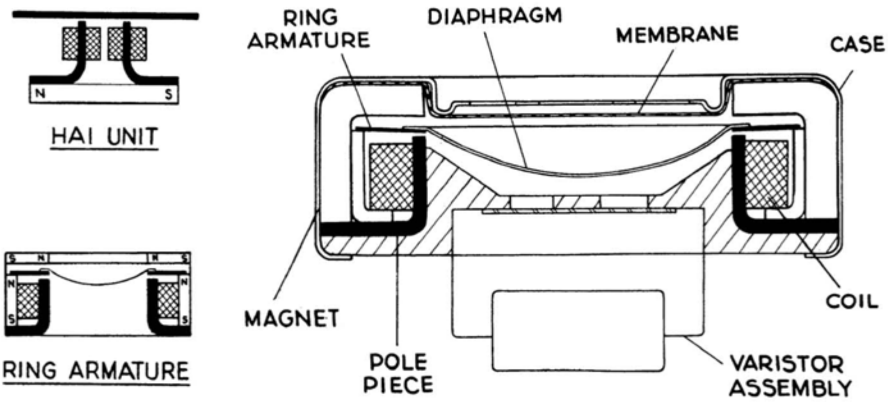

Fig. 3 - The Ring-Armature Receiver

The upper illustration at the left of Fig. 3 is a schematic arrangement of the old receiver, the HA1 unit. For a structure of this type to do its job, the diaphragm must be large enough in diameter to provide an effective radiator. It also must be thick enough to provide an efficient magnetic circuit. Bearing in mind that magnetic materials are relatively high in density, it is evident that the diaphragm will have a relatively high effective mass and that the high-frequency area cannot be filled in with this kind of device.

One of the things we tried was a composite diaphragm in which the center was magnetic and the outer portion was low-density, non-magnetic material. The reduction in effective mass which resulted from this construction was negligible.

The solution of the problem lay in reversing the arrangement of the composite diaphragm. Instead of putting the high-density magnetic material at the center, and the low-density material at the outside, we put the high-density magnetic material at the outside, and the low-density material in the center. In this arrangement the high-density material is at a location where it contributes a minimum to the effective mass, and the low-density material at a position where it reduces the effective mass of the diaphragm.

This change results, as you can see, in a very different type of receiver. The diaphragm becomes a ring of magnetic material, supporting at its inner edge a dome of low-density, non-magnetic material. I will pass one around so that you can look at it in more detail. Because it is a ring supporting the dome at the center, we call it a "ring armature".

Obviously, with a structure of that sort, it is necessary to provide an entirely different magnetic circuit. Without going through the various steps in the development, we arrived finally at the structure shown in Fig. 3. The outer edge of the ring is supported on a non-magnetic seat, and provision is made for driving the ring at its inner edge. This calls for a polarizing magnet of special design, and a pole piece which is separated from the ring by an air gap. The voice coil is located in the space between the pole piece and the seat.

Now, a few words as to the magnet itself. There are a number of ways that one could look at it. One might say, "This is just a form of balanced armature receiver in which the diaphragm is attached to the inner edge of the armature instead of through a connecting rod".

I think a better way is to consider that the cylindrical portion of the magnet provides the polarizing field, and the portion parallel to the armature is a polarized shunt. If the shunt were not present, all the flux threading the gap would pass through the armature. On the other hand, when the shunt is provided, a large portion of the flux threads this path, builds up the flux in the gap, and increases the efficiency of the magnetic circuit. In other words, in the ring-armature structure we reduce the mass to extend the frequency range and change the magnet circuit to increase the efficiency.

These changes result in a different sort of receiver structure. There are two or three considerations associated with the use of a structure of this type to which I feel attention should be called. In the first place, when we increase the efficiency by the 5 db that I mentioned and provide a receiver that is linear in its response—in other words, it doesn't introduce distortion—then we are faced with the possibility of undesirably high input levels, severe clicks, etc., which result in pressures at the ear that would be troublesome. As you look at this receiver, you will notice that bridged across the terminals is a varistor, which is a part of the receiver.

This varistor is a shunt which varies in resistance with voltage. The constants are so chosen that when a high-level surge is impressed on the receiver terminals, the pressure in the ear never rises beyond the tolerable level.

It is of interest that we also utilize the voltage-limiting characteristic of the varistor in designing other parts of the instrument; for example, in designing the magnetic circuit, we are able to keep down the size and weight because of the shunt. It doesn't demagnetize; the shunt bypasses demagnetizing currents, and consequently we can design the magnet very much closer to the limit from the standpoint of weight.

There are two other corollary effects that are of interest from the standpoint of response. I mentioned that the response characteristic of the receiver covers a wider range and is more efficient when it is held closely to the ear.

One of the things that you always want to bear in mind in connection with station apparatus is that we put the instruments in the hands of the telephone user to use as he sees fit. We make every effort in the laboratory to design them so they will do a good job under field conditions; nevertheless, we cannot predict just how the user will handle the instruments. One of the things that a person does quite frequently is to hold the receiver loosely to the ear; in other words, there is a leakage space between the receiver cap and the ear.

The changes in design, introduced in the new receiver, have very materially improved the off-ear response. It falls off a little at the high and low ends, but is very much improved.

Another factor that results from lowering the mechanical impedance of the vibratory structure is a better signal-to-noise ratio If a person holds the receiver loosely to the ear when room noise is present, the effect of the room noise is substantially reduced. So by adopting the new vibratory system, we have done three things: We have extended the frequency range and increased the efficiency for normal use, we have secured improved response off the ear, and we have improved the signal-to-noise ratio.

I would like, at this point, to make this observation. Although we do everything we can to design the instruments to do the best possible job, the payoff is what happens in the hands of the user. We have worked out tests for making field observations and evaluating transmission improvements under actual operating conditions. The results of these tests show that not only are we getting the volume gains which I have mentioned, but in addition we are getting improvements in effective transmission due to the improvements in response. The result is an over-all gain larger than we would get on a straight volume basis.

There is just one other item on which I want to touch, and that is the arrangement of the handset as such. (Fig. 4.)

I mentioned in discussing the transmitter that we elected to split the transmitting gain between the transmitter unit and the handset. The gain in the handset itself is obtained by changing the mouth-to-ear spacing, that is, bringing the transmitter mouthpiece closer to the speaker's lips.

No doubt a question rises in your minds: namely, how does this fit in with head-measurement charts which have been discussed at previous meetings? When we designed the F-type handset (the one associated with the 302-type set), we had another problem: namely, associating the handset with the various kinds of existing mountings. In other words, in

Fig. 4 - The Handset (G1)

addition to meeting the head-size requirements, we had to design the handset for use with existing apparatus.

In the new set—and Bill Tuffnell will emphasize this phase of the problem as he goes into the other parts—the set as a whole is interchangeable with other sets but the component parts are not interchangeable. For example, you can't use the receiver and transmitter without associating the equalizer with them. The set is designed on the basis of getting the optimum out of all components.

The new handset is shorter than the old one, in order to increase the output of the transmitter. We feel that it gives us a better all-round set and one which is higher in efficiency.

I mentioned the decrease in weight. We are down to something of the order of 12.5 ounces, a reduction of about 25 per cent in weight as compared with the F-type.

The other item which I wanted to touch on is the matter of costs. In all of our design work, we are concerned not alone with the first cost of the apparatus, but rather with costs in the aggregate; that is, not only the first cost but also the over-all cost. As a part of the survey which I mentioned, we took a very careful look at maintenance cost as related to the present 302-type set. Now, one of the things that stood out was that, whereas we had made very substantial reductions in maintenance expense in many areas, we had not improved cord maintenance to the extent that we had hoped we might. Hence, in designing the new set, considerable emphasis has been placed on reducing the expense involved in maintaining cords.

You will recall that we have used fabric-covered cords for a considerable length of time. As a forward-looking matter, we felt that we should seriously consider jacketed cords. Based on our laboratory tests, we expect decreased maintenance by using a jacketed cord, when we tie in certain other features that I want to mention.

You know from your own experience that one of the weak spots in many pieces of electrical apparatus is the point where the cord enters the piece of apparatus and is bent repeatedly. In the new handset cord, you will notice that there is a grommet at the point of entrance. This grommet reduces the sharpness of the bend, and much less breakage results. The grommet does a number of other things. One is to close the entrance hole. It fits tightly and cuts out acoustic leakage and interfering noise. It does another thing which will be of interest to you. If you have ever tried to change a cord in one of the old handsets, you know it is quite a fussy job to get into the restricted space with a screw driver. In the new cord, there is a slot in the grommet. You don't assemble the cord with a screw but just push it down into a recess in the handle. The cup which carries the transmitter terminals, holds the grommet down in place.

The other point I want to make is that the new cord has four conductors, not three conductors. In a three-conductor cord there is a transmitter lead, a receiver lead, and a common lead. The common lead serves both as a transmitter and receiver conductor.

You might say, "Why do you add a fourth conductor?" Here again we are shooting at maintenance. When a common conductor is used for both transmitter and receiver, one of the conductors in the receiver circuit carries current. If some of the strands of this conductor break, a situation develops where the resistance varies as the cord is flexed, and noise is heard in the receiver. If the two circuits are segregated, the cord can be used much longer before the same amount of cord noise develops. We feel that we are going to gain sufficiently in cord life to off-set, with some margin, the cost of the additional conductor.

There is one other point which I would like to make. You will recall that in the present handset the cord terminates in the transmitter end, and two wires lead through the handle to the receiver. In the new cord, the wires that go through the handle are a part of the cord, just an extension of the leads. So we get rid of a couple of separate wires and integrate them into the cord itself.

QUESTION: What is the jacket made of?

MR. JONES: It is neoprene. That is still subject to investigation in the Laboratories. In any jacketed cord, one of the problems is the possibility of the surface rubbing on light-colored material and soiling it. So we have to guard very carefully against the matter of smudging. The question of the best jacket is still a matter for investigation here in the Laboratories. But, in order to get things rolling, we are using the best material available.

The over-all transmission chart in Fig. 5 gives you a picture of how the various factors are tied in together. The results obtained from a transmission standpoint depend on the particular circuit used. You will notice that the receiving efficiency of the 302 set falls off quite rapidly. In the new set, we are getting a substantially constant receiving level with loop length; in other words, we are getting the equalization we looked for.

In the new set, the differences in level between the extremes of transmitting efficiency have been very materially reduced. We still get some falling off in transmitting level with loop length. This is due to the fact that two factors are involved. First, there is the circuit loss due to the longer loop; and second, the power supplied to the transmitter drops off as the distance from the central office is increased. While we have been able to correct for the circuit loss, we still have the power supply loss.

Looking at the sidetone, you will see that for this set of conditions the sidetone is lower throughout the loop range. As a result, we are able to take full advantage of the transmission improvements.

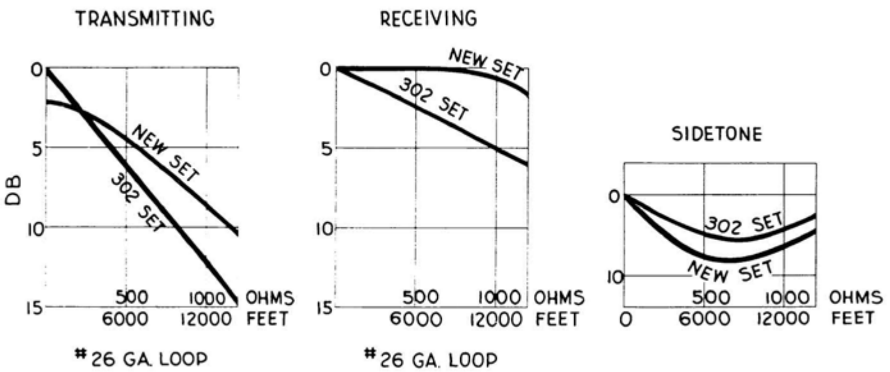

Fig. 5 - Volume Loop Losses of the New Telephone Set and the 302 Set (48 Volt x Bar)

COMPONENTS OF THE NEW TELEPHONE SET

W. L. Tuffnell

I intend to talk about the telephone set itself, principally the lower part exclusive of the handset. I guess most of you have seen the new set before. I will put it here alongside the old 302.

You immediately see that the new set has a lower silhouette than the 302. I think that is a trend in appearance design exemplified in a good many items at the present time.

As you know, Henry Dreyfus is responsible for the appearance design of this equipment. He has been a consultant on the handset and the appearance of the set itself has been integrated in his organization.

If some of you are seeing it for the first time and don't like it. don't worry too much about it. Some of <u>us</u> didn't like it the first time we saw it; but the people most critical of the set at first glance are rapidly changing over and are becoming convinced that there is something to the set appearancewise.

We had many discussions with the Western Electric people in the formative stages of the job, while we were integrating the designs with them for manufacturing considerations. As you know, the manufacturing people are in general a pretty conservative, hard-boiled lot—we come out there with a handset that looks like this, and sometimes they are not very complimentary in what they say about it. However, I remember going back there just a few weeks ago, and the chap that was most critical of this handset design said, "You know, I think Henry has got something there. The more I see it, the more I like it." We have noticed in the Laboratories that those people who have used the set and had it on their desks, get to like it very much.

One outstanding feature of the set is the dial. Quite a bit of emphasis has been placed on the dial treatment, from appearance and from function. The dial is larger. A larger dial number plate takes up pretty much the whole front of the set. I will get into the dial construction in detail a bit later.

The housing of the set is thermoplastic, as in the ultimate design of the 302. It is cellulose acetate butyrate, Tenite 2, and has been found to be the most suitable material for this application.

In the 500 set, we have deviated from the previous design in that the cover is just that: it is a cover. In other words, the complete set is mounted on the base. That has a lot of advantages—for manufacturing, for servicing in the field—and you can see, when you get into color, that it has advantages for that also. In other words, the housing supports nothing but the plungers, which are mounted there for convenience. The rest of the set is mounted on the base; and this can go through the production line at the shop, have complete tests made on it, and then have the cover put on as a final operation. That is a very important item. It makes the whole set easier for the installer to get at if any changes are required. As you know, previously, the dial was mounted in the housing and wired to the set, and you had rather a rat's nest of wires going all around the combination.

Now, to talk a little bit about the circuit, there are several modifications from the circuit used in the 302. The principal ones are: the induction coil and balancing network are designed to give much better side-tone balance; and there is a new item in the station set, the equalizer.

The equalizer is shown at the bottom of Fig. 1. There is a resistance lamp connected in series with your station transmitter. Across that resistance lamp, for protection, we connect a varistor. In the same glass envelope, close to the filament, is a thermistor which, as you see, is connected across the receiver. There is also a varistor, which Mr. Jones talked about, which is mounted in the handset and which is also connected across the receiver.

The transmission apparatus in the set, exclusive of the transmitter and receiver—and by that I mean the coils,

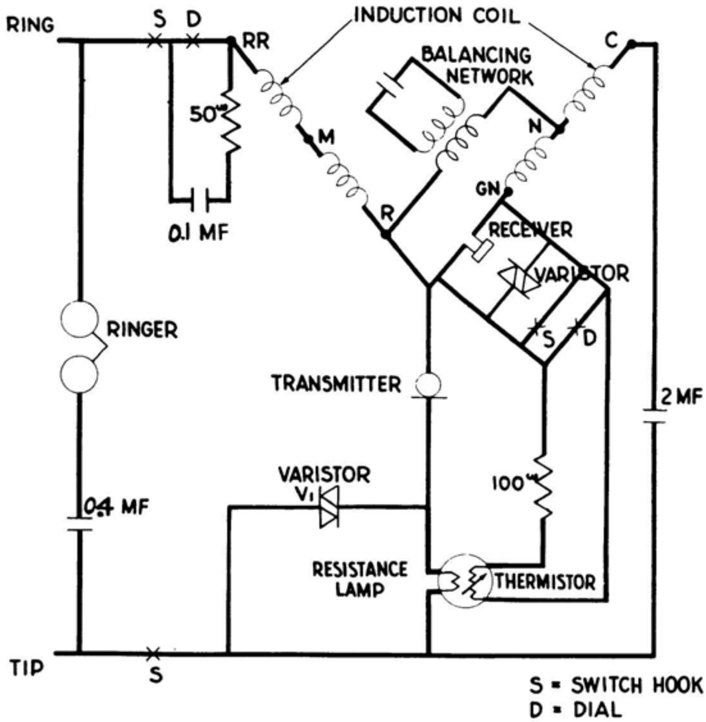

Fig. 1 - Circuit of the New Telephone Set

condensers, resistances (and there are quite a number of them)—are all mounted in a single unit. That is a departure from our previous method, when they were mounted on separate brackets, and then we wired around to make the required connections. Here is the network, in my hand. It consists of four condensers, the coils, and the resistances.

The condensers are of the metallized paper type. Metallized paper is one of the products of the reclamation of Germany.

Incidentally, I think it is interesting to know that Germany was able to do a lot of fundamental research work right in the midst of the war, and that it was carried on right up to the time the peace was declared. Sometimes we used to think that pretty nearly everyone over in Germany was shooting a gun, but that wasn't so. They came out with some very fine fundamental developments in the technical fields, and this is one of them.

Metallized paper condensers are important because they are very much smaller. You get the same capacity in much less volume. Also, they have a unique characteristic in that they are self-healing. If the connection breaks down, it will seal itself. Right after the war, there were two machines, I think, that were brought back from Germany, and Western Electric was given one of them. At the present time, we have a machine in the production plant at Archer Avenue that is, in a sense, a duplicate of the Germany machine. It has been modified to fit in with the production requirements of our own company, but in general it is the machine that was taken from Germany insofar as its basic characteristics are concerned.

Metallized paper is produced by depositing zinc in the vapor stage on a lacquer-treated paper. It is a very interesting operation and it is something that is going to have widespread application in the condenser field.

Let's get back to the network. We mount all the elements in a can, and then it is potted: in other words, there is a material poured around it to protect the elements from moisture and from mechanical harm. The can is then riveted onto the base.

I would like to talk a little bit about the equalizer, because it is something new in telephone sets—new to us and new to the field—and a very important element, as Mr. Jones indicated, in controlling our transmitting level.

Fig. 2 is a blown-up picture of the equalizer. It has two tungsten filaments. These filaments are only a half-mil (one-half a thousandth of an inch) in diameter. The wire is so fine that when I get it far enough from my eyes to be in focus, I can't see the darned thing. The filaments are coiled around a 2/1000 of an inch mandrel; in other words, we coil a little of this half-mil tungsten wire around a 2/1000ths inch mandrel, remove the mandrel, and then mount the coiled wires spaced as you see in the figure.

The thermistor also is an interesting and important element, particularly the thermistor bead. The diameter of that little bead is about the diameter of the lead in your pencil, about 30/1000 inch, and it is spaced accurately with relationship to the filament. The bead is an oxide of manganese, cobalt, and silica.

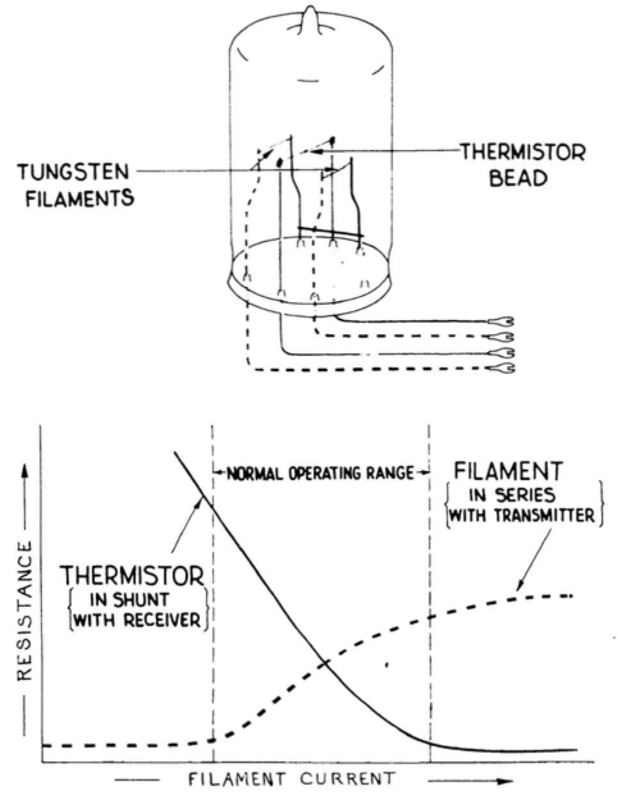

Fig. 2 - Resistance Lamp with Thermistor for New Station Set. Certain Characteristics Are Shown in the Diagram at Bottom.

Thus we have the thermistor bead, as in Fig. 2, supported between the two filaments.

Now, let me talk a little bit about what goes on in the equalizer. As Mr. Jones said, we have got more output in this transmitter than we can use on a short loop. It would be uncomfortably loud. You wouldn't like it, and the chap that you were talking to wouldn't like it.

When the filament current is high, the resistance of the tungsten filament is high and introduces a loss in the circuit. As you go out to stations farther from the central office, the loop length increases, the filament current goes down, and you operate on a characteristic like the dotted curve—the resistance of the filament going down as the current goes down. In other words, on long loops, you are introducing just a small resistance in your circuit, with a very small loss in transmission. We would like, naturally, to have the loss zero for our longest loops; but that, of course, is a practical impossibility. At our maximum loop, there is a loss of about one db.

Now, on the thermistor, this goes on: As the filament is heated, the thermistor bead, in proximity to the filament, is also heated, and that has a resistance temperature characteristic as shown by the solid line in the diagram at the bottom of Fig. 2; in the short loops where the current is high, the heat is high in the area, and the resistance of the thermistor bead is low. Understand that it is in shunt with your receiver, as noted on the diagram, so you are introducing a substantial loss. When you get down to the long-loop condition and the filament current is low, the resistance of the thermistor bead is high, so you are introducing a small loss.

These two characteristics work together—and you see that the relationship between these elements in the equalizer itself has to be very carefully controlled to produce the equalization with loop length that Mr. Jones talked about.

The equalization we get with loop length is roughly about 5 db in transmitting and 5 db in receiving, which, as you see, would bring it about to the level of the 302 set on the short-loop condition. That was the objective: not to make it any louder than our 302 set on the short loop.

DR. PERRINE: Is the tungsten filament ever incandescent, or is it always incandescent?

MR. TUFFNELL: It is incandescent on short loops. The temperature is of the same order as the temperature of the filament in a switchboard lamp.

QUESTION: Does it take very long to heat up?

MR. TUFFNELL: No; it is not instantaneous but the time factor is very short.

QUESTION: What about the life characteristic?

MR. TUFFNELL: The life of the filament should be about the same as the life of a filament in a tungsten switchboard lamp, which has been rated as somewhere about 3000 hours.

Now, I would like to discuss this dial a little bit. You notice that the characters are on the outside of the finger wheel. The reason for putting them there was at least twofold: first, it permitted visibility over a greater angle. One of the comments on the old set has been, that you had to be almost directly in front of the finger wheel and number plate in order to see the characters. When you put the characters outside of the finger wheel, you can see them over a greater angle, and that is rather important. It is particularly important when it is not convenient to have your set right at your elbow. Also, there is a sort of stroboscropic effect with the finger wheel whipping past the characters that some people have objected to.

That is not all on the right side of the ledger, putting them out there. We found out by very careful tests that dialing time went up when we moved the characters from under the finger wheel. But, we have corrected that by a very interesting little device. You will see little white spots under the holes of the finger wheel. Those spots do two things: first, they let you know when the wheel comes to rest. That is just a split second, you see, but it is a factor in dialing time. Also each spot in a hole provides a focus point on which to put your finger for the next character or number. In other words, your eye immediately focuses at the center of that hole, and you can start dialing quickly. Those dots have decreased the dialing time, a very important part of the whole design.

QUESTION: The dialing time is speeded up?

MR. TUFFNELL: That's right. By speeding it up, I don't mean speeding up the pulses as such, but the length of time it takes the customer to dial; which is the important thing, because the central office equipment is tied up while he is dialing.

QUESTION: Is the speed now equivalent to that of the dial of the other instrument?

MR. TUFFNELL: Yes.

QUESTION: What was behind the decision to eliminate the color distinction between letters and numerals on the new dial?

MR. TUFFNELL: That is a very interesting subject. Our shop would very much like to get away from the red numbered dial. We have made trials, and can show no improvement with the red numbers. There does not seem to be a reason in the world for using them. They create a manufacturing problem and increase cost. Therefore, on this design, we decided to get away from them.

That brings up the interesting matter of how we get these characters in here. This number plate is plastic. In the old set, it was a ceramic. Here we have a plastic which is the same material that we have in the housing; in other words, it is cellulose acetate butyrate. The main body of the plate is clear plastic. The characters are molded in from the underside but don't come up to the front surface of the transparent plate. Then we put white pigment in them. Then we cover the whole back with black; and you have the white numbers showing up very nicely through the clear plastic and against the black background. There is nothing there to wear off as far as the characters are concerned.

The dial is a bit like a clock. In a sense, it is a clock mechanism. But, this dial can be dropped from the height of a table or desk and the whole weight of the set can fall right on it without injury to the dialing or pulse-mechanism. I think it is rather interesting, that a mechanism of this kind, which is very carefully controlled and very much of a precision job, can take that kind of treatment.

The principal new feature in the dial, aside from what you can see, is the manner in which the pulsing is obtained. In the old dial, we had a ten-lobe wheel which gave us our pulses. In the present design, we have a single-lobe cam that goes around and gives us the pulse.

That is important in this respect: The make-and-break of each pulse has got to be the same as the previous make-and-break. In other words, we want these pulses to have the same time duration, percentage of make, and percentage of break. With a single cam, the cam action is the same for each pulse. The closer we can control our pulsing, the better we can dial over the long loops. It has been estimated that if we can control the pulsing within three-tenths of a pulse rather than, say, five-tenths of a pulse, we can dial over approximately two hundred ohms more of loop. You can see what that means in the plant. The cam and the pawl, in this new design, are made of nylon. There have not been many instances of using nylon in instruments to date, but we are just sort of getting a "feel" for nylon in applications of this kind. Nylon has been used, as you know, in women's wear for a long time. We want to take advantage of a special characteristic of nylon. Nylon is a very hard thermoplastic, and we have put these cams and pawls through operations that run into the millions without perceptible wear on the cam. Now, that is far superior to metal, and the reason is probably tied up with the thermoplastic nature of the material.

As the cam rotates, just that very tiny amount of heat that is generated by pressure and friction at its point of contact melts the nylon at that minute spot. Thus you get a microscopic film of lubrication at that place on the surface. As a result, it stands up far better than a metal cam would stand up; in other words, there is practically no wear. Understand that nylon has been used previously in bearings, and it is an oilless type of bearing. You do not have to lubricate it because of its thermoplastic nature. Most thermoplastics are not usable for applications of this kind because they tend to shrink and warp and show great dimensional instability with temperature and humidity. Nylon does not. We are going to use a lot more nylon in telephone applications as time goes on.

I have the debatable pleasure of riding in with a chemist every morning, and I asked him this morning what made the difference between a nylon that we would use for applications of this kind and the nylon that finds its way into women's hose and underwear. Ten miles later, he was still telling me the difference; but then summed it up by saying that, well, you could use the same in some cases and in some cases you probably wouldn't. Apparently, there are two basic nylons that differ very little; and, for all practical purposes, you could consider that the nylon we use is pretty much the same material that goes into women's underwear or stockings.

QUESTION: Can those component parts be plugged into the base or are they permanently attached with wire connections?

MR. TUFFNELL: I am glad you asked that question. No, they are not plugged in. They are riveted on the base. All of the component parts are either riveted or fastened with screws on the base. The equalizer network is mounted with rivets.

QUESTION: That means, if one part is defective, you replace the complete set?

MR. TUFFNELL: That's the intent. We are working along those lines, because, among other things, you have the high cost of installer work in the field. The plan is to make the components so good that there would be very little maintenance, if any; in case of trouble, take the set out, put another one in, get the defective set to a central shop or factory, and do your repair work there. I think it has been evident for some time that installer manipulations in the field are not a good thing. It is very difficult to get precise information into their hands, and with rapid turnover of personnel, you are not too sure of just what kind of job is done.

QUESTION: Do you make considerable use of the fact that there are 433 parts currently used in the set? What is the number of parts?

MR. TUFFNELL: I haven't counted them. We will do that one of these days for you. I suspect it is a bit higher. Do you know, Mr. Jones?

MR. JONES: About the same number; a little on the high side, Bill.

MR. TUFFNELL: But there are a good many, and a good many different materials in this set, which are of interest to you folks. There are some new materials that we did not have in the last.

DR. PERRINE: Before you leave that subject, Bill, will you expound a little bit on the new two-tone covers? You have shown us that one cover comes right off. I understand there are going to be pink and red and yellow and all that. Is that right?

MR. TUFFNELL: Where did you hear that?

DR. PERRINE: I heard that at the "Looking Forward" exhibit.

MR. TUFFNELL: Well, I wish I knew what we were going to do about colors, because we would like to get moving on it. The housing can be made in any number of colors, and we are working with Mr. Dreyfus to decide what the color trend should be. You can make some very attractive shades—pastels and bold colors. Just what it will turn out to be, I don't know. There will be a range. Our management is disinclined to bring that too much out in the open until the thing has jelled a little bit more. There are a lot of factors involved. We can't very well make the dial number plate in color, for example, because you lose contrast between characters and background, which is an important factor in dialing time and visibility. There are problems, but we will get around them, and there will be color and it will be very attractive when we are through.

DR. PERRINE: It won't cost too much, I hear, either; instead of costing twenty-five dollars, it might cost a dollar and a half?

MR. TUFFNELL: I won't give any figures on what it may cost; but you can see that if the installer can just go out to the field and change a housing, it should be a lot cheaper than doing the job on a small, complicated running basis in the shop.

QUESTION: Does that mean the discontinuance, therefore, of standard colors on the present sets?

MR. TUFFNELL: No, I wouldn't say so. You mean the ivory and blue and gray-green, the Pekin red and old rose that we have on our 302?

QUESTIONER: That's right.

MR. TUFFNELL: Well, I have seen them piled up at the shop, so there will be quite a number of colored sets.

QUESTION: A couple of years ago, you were doing some development work on a set that used a push button instead of a dial. What became of that?

MR. TUFFNELL: That hasn't been neglected, but it is a long-range development job.

QUESTION: You wouldn't have the housing a color and the handset itself black, would you?

MR. TUFFNELL: I don't know.

QUESTION: I might say that we were told at the exhibit that Dr. Perrine mentioned, by some authority, that the housing would be in color and the handset itself would be black.

MR. TUFFNELL: That is a possibility.

QUESTION: Just one more question. What is that little disc right in the back here?

MR. TUFFNELL: That is the varistor. And it is put in there to prevent burning out of the filament when ringing may inadvertently get through it, or high electrical surges.

We also have a new ringer in this set. The ringer has been completely redesigned. It is still the two-gong type, but our magnetic circuit has been completely revised. Fig. 3 is a schematic chart or picture of the ringer. The upper one is the present ringer, and the lower one is the new ringer.

The old ringer had a magnet in "U" shape, of cobalt steel. The new ringer has a very small magnet of Alnico-5, one of the newer magnetic alloys; and we take advantage of the better magnetic qualities to reduce size.

We use a single coil in the new ringer instead of two coils, getting some economy in copper. The impedance of this

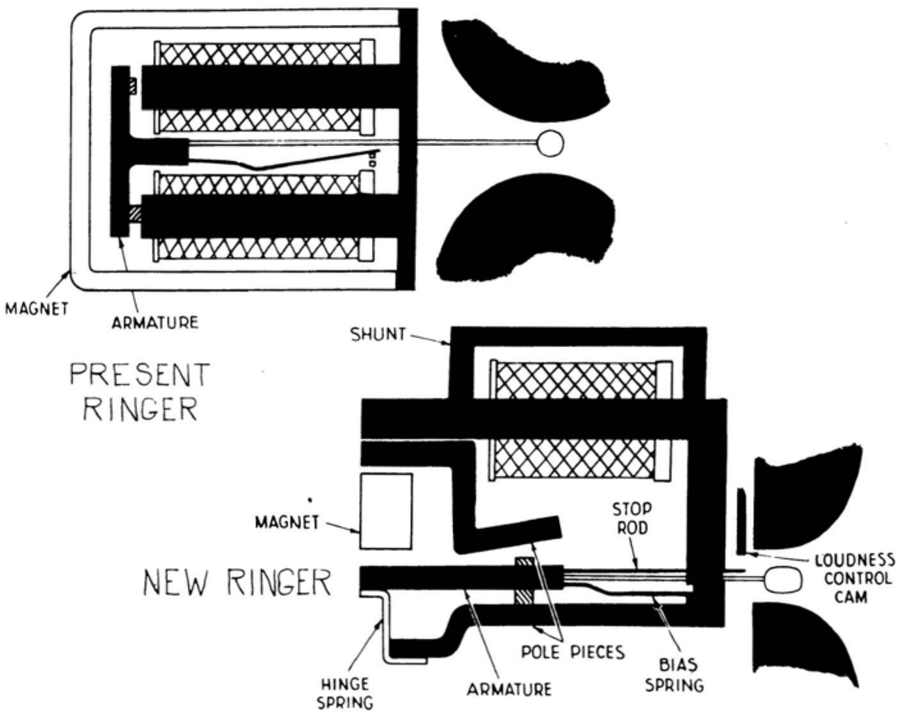

Fig. 3 - Present Ringer Compared with New Ringer

ringer has been increased appreciably so that we are getting less bridging loss when we have multiparty sets. Incidentally, this new ringer can be used five at a time whereas the old ringer was limited to four.

At the shop, a ringer is hemmed in with a lot of requirements: it should ring with a certain current and not with another current, because of cross-tapping, bell-tapping, and so forth. Out in the shop, the old ringer was balanced for non-operate and operate by doing a lot of manual bending on the biasing spring. In the new ringer, all that is done automatically. We have a machine that was developed here at the Laboratories, which balances the system for operate and non-operate by alternately knocking down the magnet (in other words, demagnetizing the magnet slightly); and then, if the magnet was demagnetized a trifle too much, putting a little bend into the biasing spring.

This ringer still has a biasing spring, but there are only two positions for it, whereas the other had three. But that whole adjustment is done automatically. We gain two things there. The adjustment is no longer manual, and that is expected to result in a more uniform product; also, with the demagnetizing of our magnet, we have a ringer that is stable in the field. The old ringer was subject to some deterioration because of loss in magnetic characteristics of the magnet. Here, we knock it down just the way we do in a receiver in order to get a stabilized system. That, we think, is something that will be an important advantage.

The gongs are lower in pitch than the old ringer, and I think more pleasing in tone. The two gongs are separated in fundamental frequencies so as to get a musical sound. The frequency of one is, I think, about 1240 and the other, 1590. One of those is E flat, I believe, and the other is G above high C.

Another important design feature in this ringer, introduced for the first time as part of the design, is a resonator. The resonator is built right in the ringer. It is a little aluminum detail that fits under the gong. It is built in as part of the ringer, and all ringers are so equipped. Probably you will recall that in the old design, resonators were added in the field as and where required.

Now, the resonator has the characteristic of building up the fundamental frequency of the ringer. Fig. 4 shows the magnitude of the increase by the use of the resonator. The left diagram is for the old ringer. I mentioned that the fundamental of the new ringer was lower: note here that the old frequencies are 1620 and 1970; now they are 1240 and 1590.

Notice that the fundamental is very much lower in output level than the overtone. As you know, on a bell we do not have harmonics. We have overtones. They are not harmonically related. We have what they refer to in bell language as "partials." We do not have anything like the second harmonic and third and so on, as you have in the vibrating string. For that reason, it is more important than ever to bring out this fundamental frequency of the bell in order to get a pleasing sound.

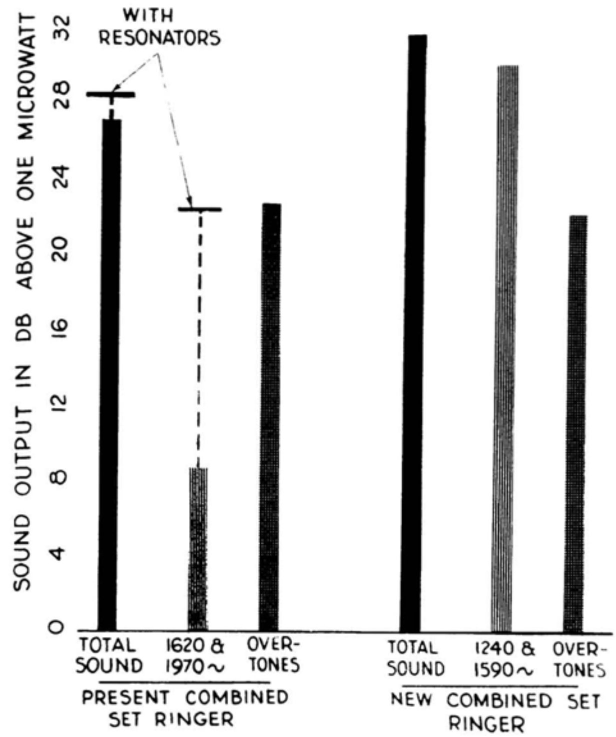

Fig. 4 - Sound Output of the Ringer

The dotted lines represent what we did in the field by the application of a resonator to the present ringer; in other words, we built up the fundamental tremendously. The resonator itself on that ringer increased the fundamental output level about a hundred times; in other words, it moved up about 20 db.

The diagram of the new ringer (on the right) shows some gain in total output over the present ringer, and the fundamental here, you see, is very much higher than the fundamental in the old ringer. I am going to ring it, and I believe you will like the sound of it. There have been very few criticisms of the sound of the ringer.

We have one other feature, a ringer adjustment. We are planning to permit the subscriber to change the level of his ringer. We get about 15 db range in volume level by the manipulation of a little wheel that is in the bottom of the set. We move one gong in its relation to the clapper ball. At the same time, we move a cam that provides a stop for the stop rod.

You know, when you ring a ringer, you don't hit the gong with a clapper ball, but in a sense you throw the ball against the gong. You swing the clapper rod up against a stop, and then the ring is obtained by the inertia effect after it hits that stop, swinging the ball over and hitting the gong. That is what gives you that clear signal. If the ball simply came over and hit the gong, you wouldn't get that clear tone. We have gone to the extreme in this ringer, of putting the clapper ball loosely on the clapper rod. In other words, we get a little throw of that clapper ball at the last instant, just before it hits the gong; and that results in a very much more pleasing tone.

The ringer control is down on the bottom of the set. We wanted it out of the way so that youngsters and others wouldn't fiddle with it too much; but we wanted it in a place where they could get at it if they wanted to. There is a little cam arrangement right at the bottom. I can turn it. There are three steps, or four including the last position, and that gives about 15 db of adjustment.

DR. PERRINE: A lot of these fellows don't know what 15 db is. What is it?

MR. TUFFNELL: Well, I mentioned before that 20 db is a hundredfold; and 3 db is twofold. So 15 db would be 32-fold.

DR. PERRINE: Thirty-two times' difference in loudness?

MR. TUFFNELL: That is correct.

MR. TUFFNELL: I would say that the introduction of this feature has not been without some concern on everyone's part, but we have a lot of faith that it is going to be very well received. Oftentimes, installers are asked to go out to a home to cut down the sound of the ringer. That is an expensive proposition. I think the thing is foolproof insofar as manipulation by the subscriber is concerned. Some people probably won't fiddle with it at all; other people will be playing with it constantly. You know how that sort of thing works out. You can visualize in apartment houses, where a youngster is probably sleeping in close proximity to the living room; you may not want to wake him up, so you turn it down.

QUESTION: Can the repairman make any further adjustment?

MR. TUFFNELL: The installer can shift the position of the biasing spring to accommodate requirements of long or short loops.

Fig. 5 shows what happened to the position of the sound control when we put a hundred of these sets out in the field

		AS INSTALLED				
	POSITION	1	2	3	4	TOTAL
		NUMBER OF SETS				
	4 (LOUD)	1	2	39	18	60
FOUND ON REMOVAL	3	0	1	15	0	16
	2	1	1	9	1	12
	1 (SOFT)	3	2	7	0	12
	TOTAL	5	6	70	19	100

INCREASED / UNCHANGED / DECREASED

Fig. 5 - Positions of the Volume Controls

for trial. In the table, "POSITION" indicates the position of the sound control: 1 for "Soft", and up through 2 and 3 to 4, which is "Loud". The line of numbers marked "TOTAL" at the bottom of the tabulation shows the position of the sound control in the sets when they were installed, and the column marked "TOTAL" at the right shows the position the control was found in when the sets were removed. The four columns in the middle give the break-down of the totals at the right.

When those sets were installed, the sound control was in Position 1, Soft, on five of them; in Position 2 on six sets; in Position 3 on seventy sets; and in Position 4, Loud, on nineteen. After a good many weeks of use, we went out and looked at the ringer adjustments of those sets, and we found this: that in Position 4, the Loud point, there were sixty where we had had nineteen to begin with; in other words, a lot of people made them louder. But where we had had five in Position 1, Soft, when the sets were installed, we found on removal that there were twelve in that position. So a lot of people made them softer. Of the hundred sets, there were thirty-seven that showed no change in the position of the sound control.

I don't know whether this illustrates anything other than that people like to fiddle with something like that. I think we can expect a lot of people to make them softer and a lot of people to make them louder. Of course, that is the reason for giving them a ringer adjustment.

QUESTION: How about the possibility of an increase in "don't answers" due to the volume of the bell being reduced?

MR. TUFFNELL: I have some data on that. That is a smart question, and something that we concerned ourselves about. In the field trial, the percentage of "don't answers" on roughly 2500 observations was 13.8 per cent on the new set and 12.6 per cent on the old one. There is a difference of about one per cent. I don't know whether our sample is large enough to be significant; but the difference is not great at any rate. Of course, if everyone put them in the low notch there would be an increase in the number of "don't answers". I think that is understood.

In Fig. 6, there is a tabulation of the comments resulting from a number of these sets which were put out into the field. Some observations were made on transmission, comments were reported, unsolicited comments noted on the general appearance, behavior observed (the reaction of the customer to the set). We have them shown here in graph form, which I think is very interesting.

Looking at the legend for a minute, where a black bar is crossed by thin white lines running down to the left, it indicates favorable comments on the set. If the white lines run down to the right, that portion of the bar indicates unfavorable comments. Where we couldn't decide whether more liked it than disliked it, the bar is solid black; and the blank or white portions of the bars mean "No Comment".

Over-all preference for the set is shown here. It is very definite, a high preponderance of favorable comments

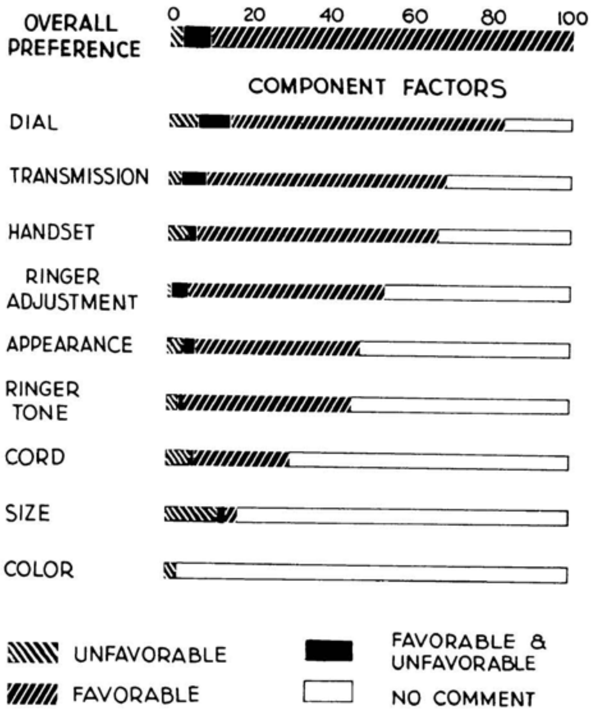

Fig. 6 - Subscriber Reactions

on the set as a whole. It shows that out of a hundred people, there were only three that decided they did not like the set. There are ten in the area where it was some "Yes" and some "No"; but the balance, in other words, some eighty-odd indicated a very definite preference for the set.

Now, these are listed in the order of volume of favorable comments, and curiously enough, the dial received most favorable comment. That was on general appearance, use of the dial, and so on. Apparently, the people liked to have that number plate outside of the finger wheel. It permits a greater range of vision, and the fact that the angle is lowered (the dial is nearer horizontal) is an important factor, too. It makes it more convenient to dial. You can dial standing up; and you can dial without moving your set around, because you have a greater component tending to push the set down on the table than you have in the present set. That is an important item.

On transmission, we have a very definite advantage. Here some sixty-odd per cent show very definitely that they noticed the improvement in transmission. Transmission is something on which you don't always get a comment. People take those improvements for granted, it seems. When they look at a set, they will have a definite opinion; but they seem to think that these gains in transmission should come naturally. But we have many unsolicited comments on the improvement in transmission.

The handset is generally liked. The ringer adjustment is liked. Appearance is liked. Ringer tone is approved. The cord is not quite as outstanding, but some six or seven per cent didn't like it as well as the fabric cord.

And here we have the one case where more people disliked the set than liked it, and that is the matter of size. I can understand that. The base of this set is larger than the old one. That means it is going to take up a bit more room. The size is not without merit, however, for it makes the set more stable and facilitates dialing. The set is larger because there are more things in it; we have reached the point where we have no waste space, because we have more items inside it. On this matter of size, we have incorporated in this set some features that aren't in the 302. In other words, we are attempting to combine in the one set several of the features in order to cut down the number of codes required.

QUESTION: On the question of size, wouldn't the response be affected by the built-in telephone niches?

MR. TUFFNELL: That is correct, and that is why these comments come in. As a matter of fact, you hit that right on the head. Most of these comments, when we run them down, were from people that had telephone niches in which the 302 would just fit, and this was a bit cumbersome to put in there.

QUESTION: What could the objection be on ringer adjustment?

MR. TUFFNELL: There was one person out of a hundred who made that comment. I don't know what the objection was, unless someone thought it was not a good thing to put in a set, because it might get out of order.

MR. TUFFNELL: These were the responses in a trial made in Akron. They were not Telephone Company personnel. They were just general run of subscribers. I don't think any selection was made other than to select the area. There was a selection made in the sense of wanting to get certain loop lengths, and so on, in order to bring out the capabilities of the set, but insofar as the persons using the set, I don't think there was any consideration given to that.

QUESTION: I have a question on a matter that was passed over rather hurriedly, which looks like a big problem in our area; and that is the substitution of black letters and numerals on the new set for the red and black on the old 302. I can see our Traffic Department with what hair they have left standing on end because of the trouble we already have with dial errors in our area.

MR. TUFFNELL: Most of your dial errors are centered around the O and the zero or the l and the 1. Do you find that making the numeral in red differentiates the zero from the O?

FROM AUDIENCE: Well, we can point it out to our subscriber in dial instruction.

QUESTION: Were there any comments on that particular phase out of these hundred cases?

MR. TUFFNELL: Not that I recall, no.

QUESTION: Are those sets still in service in Akron?

MR. TUFFNELL: No, they have been brought back here for test purposes, to appraise what the service did to them, re-test, and so on.

QUESTION: It is a little off the track of the handset; but I found, in trying to explain dial use to some people that if you tell them not to say O in the number but to say zero, you clear the problem up very readily. In fact, I found that that went over easier than trying to tell them red and black.

MR. TUFFNELL: I quite agree with you on that because I have heard that expressed by other people, too.

We are closing down on the number of varieties of sets in the interest of economy of manufacture. In this set, for example, we will have two types—one dial, one manual. They will take the place of eleven sets of the 302 type such as the 302, 307, 304, and 308; in this new set we have new features, such as extra switch contacts on the switch, to permit such varied uses.

QUESTION: What about the breakage from dropping of the new set compared to the old?

MR. TUFFNELL: (Throwing the instrument on to the floor) This one has been given the same sort of treatment that the 302 set has been given, and it stands up just about as well. We have used that as a bogey (throwing the instrument off again) because the 302 set has performed very well in the field from the standpoint of maintenance caused by breaking. Since you brought that subject up, let me pass this around and let you take a look at the ribs in the housing. We did not have those in the first design. They were put in subsequently just to strengthen the housing. We got some breakage in the first models that were built.

QUESTION: How about your thermistor unit?

MR. TUFFNELL: That is one of the items that we had considerable concern about when it was planned to put it in. We have made dropping tests on sets with thermistors in them, and they can be made to stand up.

QUESTION: It looks like that dial comes 'way down in the fore part of that cover. Are there going to be provisions for the keys in the base?

MR. TUFFNELL: That will be a different housing. Your four-button and six-button key sets have got to go through the gamut of development work, and they will be built in a different housing.

QUESTION: The type of set that is being used experimentally in Media, Pennsylvania, tone-dialing, is that in the picture?

MR. TUFFNELL: Yes, that is definitely in the picture.

QUESTION: How about the cost of this set?

MR. TUFFNELL: It is a bit too early to say much about the cost. The complete set will likely be a bit more. There are more things in it. I think it is unlikely that it will be right down to the price of the 302, although you can't tell. We have been working very closely with our Manufacturing Department on that phase of the job and they have made many suggestions. We have a program of cooperation with them on the economics of designs and we have gone a long way on it already. I don't think the new set will cost very much more when we are all through.

QUESTION: When is production scheduled to begin?

MR. TUFFNELL: The matter of production is a bit complicated because of the impending move of the station plant to Indianapolis.

QUESTION: You started to tell us something about the new materials?

MR. TUFFNELL: Nylon is one of them. The whole equalizer is new. The thermistor bead is a new material. Tungsten filament is new as far as the station set is concerned. The fabric dome on the diaphragm is a new part.

MR. JONES: I might comment on that briefly. Those of you who were here at our first session after V-E Day, when we talked about wartime developments, saw what we had done on high-powered loud speakers for military use. You will recall that we had developed a diaphragm with a fabric section. We have applied that principle to the dome of the new diaphragm. It is a very rugged dome, and you can flex it back and forth and it doesn't affect it.

MR. TUFFNELL: If any of you are interested in looking at the new booth that has gone into production, we have one over there. There is a new beige treatment of the walls, a new light, and a ventilator.

DR. PERRINE: I would like to ask one more question before you adjourn. Jones and you have pointed out this 5 db gain in efficiency. Can you translate that for this group; what that would mean in loop length up in Duluth, Minnesota, in Vaill's territory? I have been there, and that is a one-dimension town: In other words, would twelve miles be the limit to which the old set would work pretty well? Will this extend it to fifteen miles, twenty miles? Will you translate that into some distance?

MR. JONES: I can't do that very definitely. You know, in utilizing a thing of this sort, it is usually spread around, that is, you use part of the gain in the central offices, and you pass along a part to the user. As I recall, the statement was made in the case of the 302 set, that the transmission improvement was equivalent to moving the subscriber in about half the distance to the exchange. According to all indications, we are going to gain from this new set about as much as we gained from the old set. It won't all be taken up in increased loop length, obviously. It will be spread around. It is a very substantial gain.