K. E. Hammer

Handsets with Transistor Amplifiers

THREE TYPES of telephone handsets which contain transistorized amplifiers are now providing special services for telephone users. Miniature electrical components and circuit assemblies have made it economically possible to design small transistor amplifiers that fit easily inside the handsets.

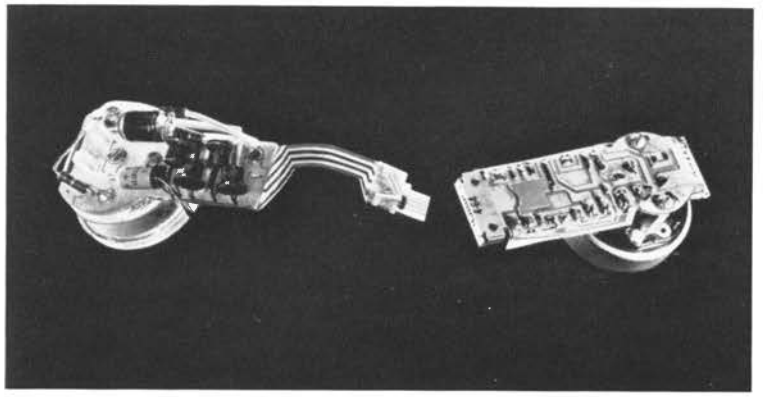
One of these handsets—the G6A—is primarily intended for persons with impaired hearing and provides gain to increase the loudness of sounds from the telephone receiver. Another type, the G8A, is similar to the G6A but is modified to improve telephone reception and transmission in noisy locations. The third—the G7A—is intended for persons with weak speech. It provides gain to increase the output signal from the handset transmitter.

These three special services have been available to telephone users over the past decade through 532 (RECORD, *October* 1955), 535, and 536 type telephone sets, respectively. Each of these telephones is a basic 500 type set with a small 151 type transistor amplifier and associated components mounted in the base of the set or in the handset. These three sets have given excellent service over the years. However, as the variety of telephone sets has been increased to include PRINCESS® telephone sets, CALL DIRECTOR® telephone sets, multibutton, card dialer, and other types, providing amplifier type models of each new addition to the telephone set family has been impractical. Additional amplifier models for each of these types would greatly increase the number of telephone set codes and would multiply inventories throughout the Bell System. Furthermore, in some sets there is insufficient space for the amplifier.

A logical solution to the problem is to house the amplifiers with the transmitter and receiver units inside the handset handle. With this arrangement the special services which have been available on a limited basis in the past can now be provided at almost any telephone location, regardless of the type or color of set, by simply replacing the standard handset with the appropriate amplifier type.

Housing the amplifiers in handsets instead of in the telephone sets has been accomplished in each case with no degradation in performance. Since the 532, 535, and 536 sets have satisfied

Handset components are shown above. Note volume control plate.



Printed circuit boards are the heart of the transistorized sets.

the needs of many telephone users over the past decade, the corresponding handsets have been designed to have similar operating characteristics. Externally, these sets are similar to the familiar G3 handsets used on most 500, 600, and 700 type sets. The only visible difference is a plate on the inner side of the handle on which the volume control is mounted. This plate is shown in the top photograph above. Internally, the handsets contain transducers, electrical circuits, and components.

When these handsets were designed, many of the small components used were available commercially. Others, however, had to be developed. For instance, the microminiature connectors, the flexible printed circuit assemblies, and the small switch for the G8A required considerable design and development effort to obtain reliable, economical assemblies.

The G6A Handset

The top diagram on the next page shows the circuit schematic for the G6A. On the left in the diagram is a simplified version of the telephone set network. As in G3 handsets, a four-conductor cord is used to connect the handset to the network. The amplifier inside is inserted electrically between the receiver terminals of the network (R and GN) and the receiver unit. In an unamplified handset, the yellow and green cord leads would be connected directly to the receiver and the red and black leads would be connected to the transmitter.

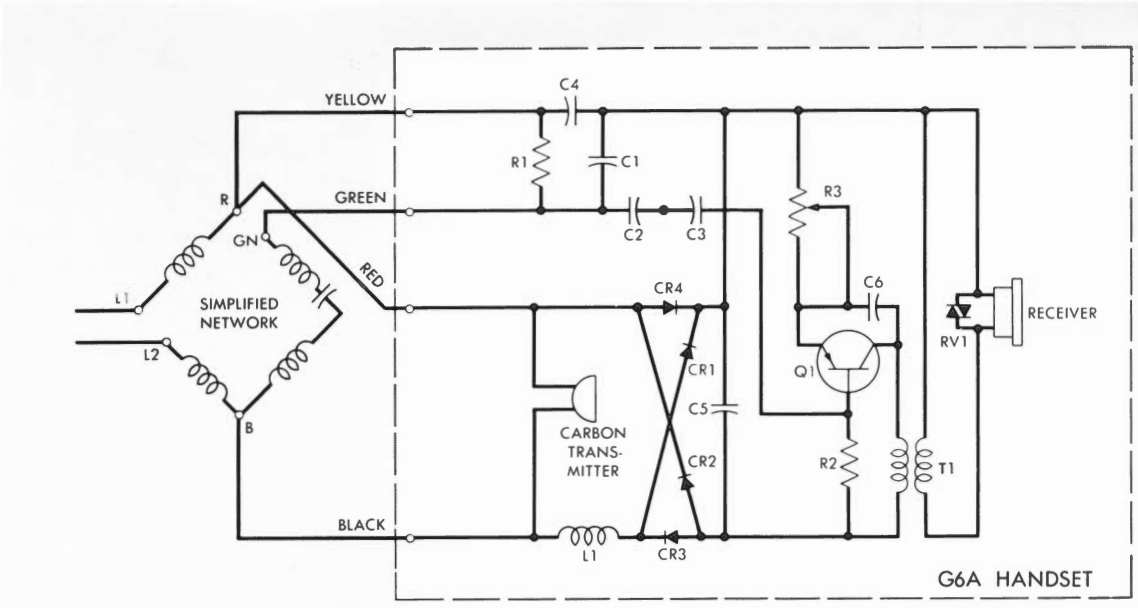
A single Western Electric Co. 12-type PNP transistor in a common emitter configuration provides approximately 25 db gain for the received signal. The amplifier input impedance, between the emitter and base terminals of the transistor, is suitable for direct coupling to the telephone network. The output impedance, between the collector and emitter, is matched to the receiver unit through a small stepdown transformer.

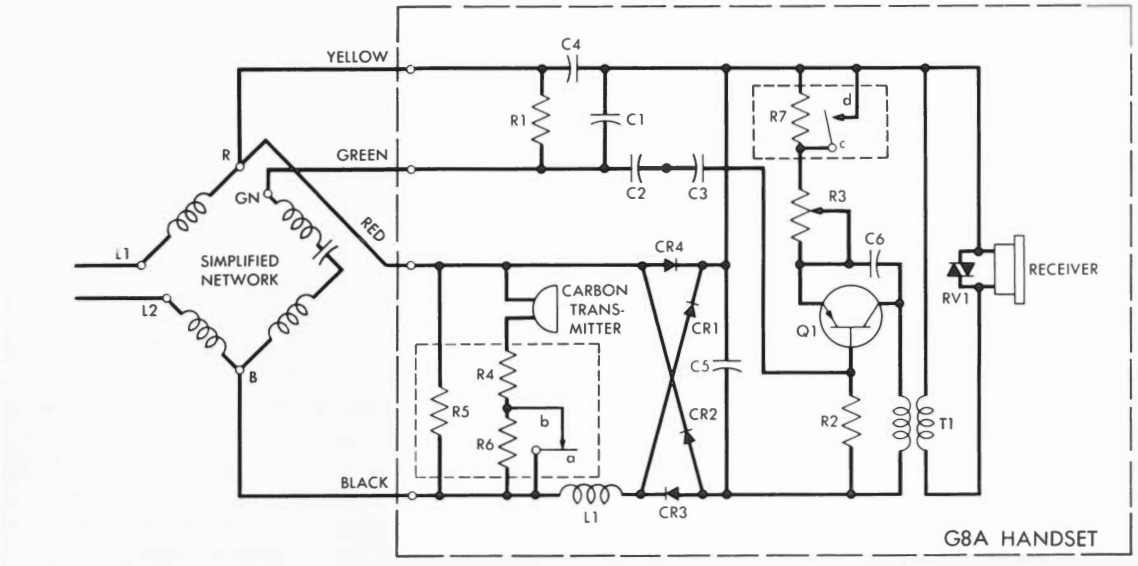
Resistor R1 and capacitor C1 stabilize the input impedance and suppress high frequency radio or TV signals that might interfere with the audio signals. Items C2, C3, and C4 are small blocking capacitors. Two capacitors, C2 and C3, are connected in series, but poled in opposite directions, to limit leakage currents, regardless of the polarity of the dc bias across them. Capacitor C6 prevents oscillations which otherwise may occur under some operating conditions.

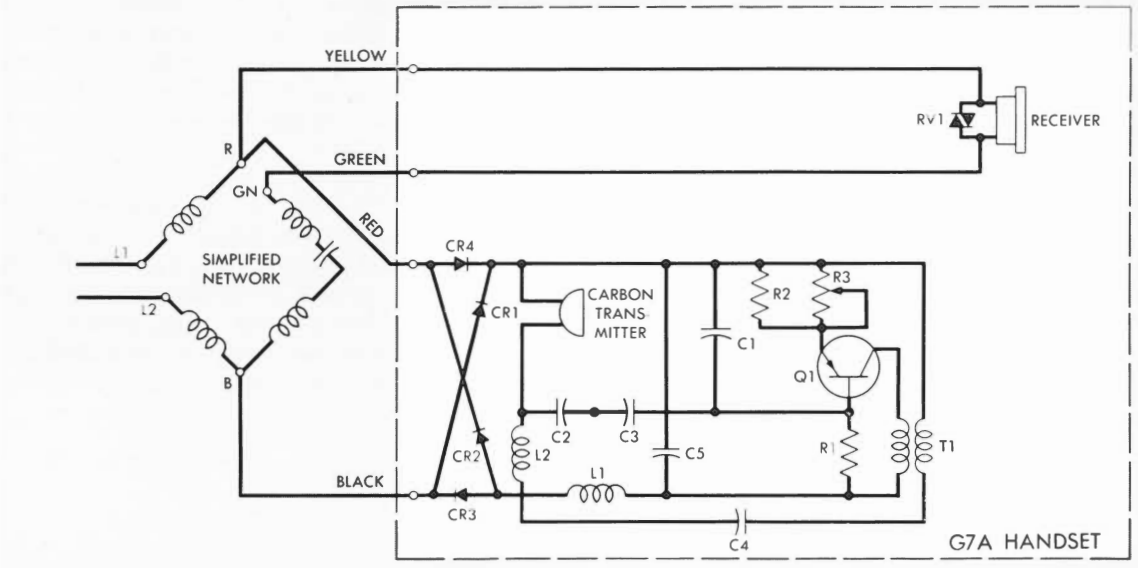
With the volume control potentiometer R3 shorted, the amplifier operates at full gain with no negative feedback. At other settings of the volume control, R3, in series with the emitter, reduces the gain; also, it provides negative feedback to stabilize the circuit and minimize differences caused by variations in component characteristics. With the volume control set near minimum gain, the performance of the handset is essentially the same as a G3 (nonamplifier type) handset. Consequently, the amplifier does not have to be switched out of the circuit when used by people with normal hearing and no gain is required.

As shown in the top diagram on the next page, power to operate the amplifier is obtained by diverting a small portion of the direct current from the carbon transmitter. Although this causes a loss in output from the transmitter of about one decibel, it is a small penalty to pay for the relatively large gain available in the received signal. The base resistor R2 has been selected to limit the amplifier current to approximately two

Circuit schematics for the G6A, G8A, and G7A handsets are shown (top to bottom) at the right.


YELLOW
GREEN
RED
BLACK
R
GN
B
L1
L2
SIMPLIFIED NETWORK
C4
R1
C1
C2
C3
R3
C6
CR4
CR1
C5
CR2
CR3
L1
CARBON TRANS-MITTER
Q1
R2
T1
RV1
RECEIVER
G6A HANDSET


YELLOW
GREEN
RED
BLACK
R
GN
B
L1
L2
SIMPLIFIED NETWORK
C4
R1
C1
C2
C3
R7
d
c
R3
C6
CR4
CR1
C5
CR2
CR3
L1
CARBON TRANS-MITTER
R4
R5
R6
b
a
Q1
R2
T1
RV1
RECEIVER
G8A HANDSET


YELLOW
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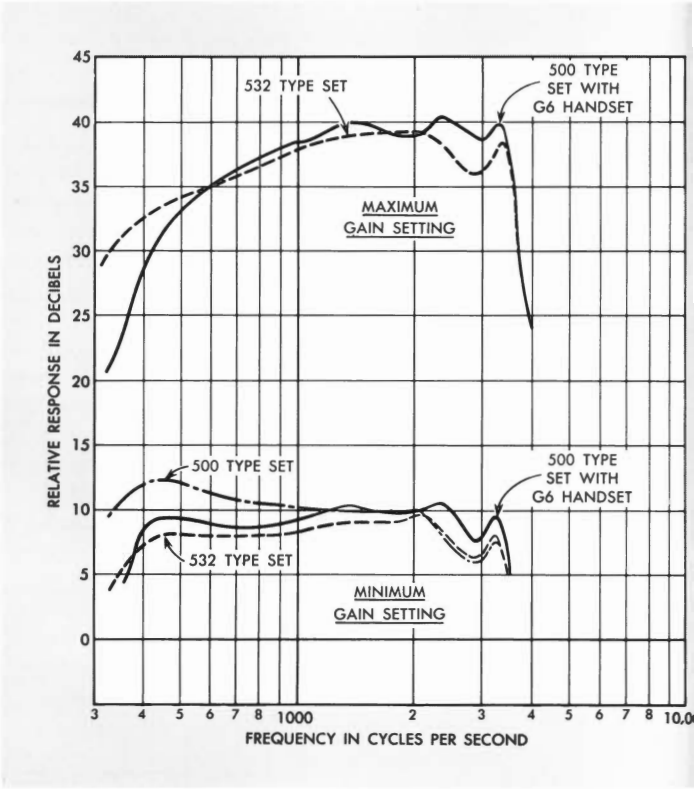
SIMPLIFIED NETWORK
Rv1
RECEIVER
CR4
CR1
CR2
CR3
CARBON TRANS MITTER
R2
R3
C1
Q1
C2
C3
L2
L1
C5
R1
T1
C4
G7A HANDSET

milliamperes on long loops and five milliamperes on short loops. This current is filtered by inductor L1 and capacitor C5. The four diodes—CR1 to CR4—form a polarity guard which always biases the emitter of the transistor positive relative to the base, regardless of the voltage polarity across the transmitter.

Printed circuit boards on which most of the components are mounted are shown in the lower photograph on page 160. The flexible printed circuits are sandwiches made up of .005 inch Mylar film, .0027 inch copper conductors, and .0005 inch Mylar film. The .0005 inch Mylar is used to protect the thin copper conductors and to facilitate soldering operations. The flexible printed circuits are cemented to 1/16 inch thick phenol fibre boards to stiffen the assemblies in areas that support other components.

The volume control is mounted on the plate which fits in the center of the handle. A two conductor microminiature plug is used to electrically connect the volume control into the circuit. The four diodes that make up the polarity guard and the associated filter components L1 and C5 are mounted on the printed circuit fastened to the transmitter cup. Four screw terminals on this circuit provide means for connecting the spade tips of the handset cord conductors to the amplifier. A four conductor microminiature plug is used to electrically connect this board to the receiver board. The remaining components are mounted on the printed circuit which is fastened to the receiver unit. This circuit is terminated electrically in a microminiature connector. To assemble the handset, the cord is threaded through the cord hole, then out of the transmitter opening so the cord tips can be fastened to the screw terminals on the transmitter board. The transmitter and receiver units, with the associated boards, are placed in the handset and held in place by the handset caps; the two microminiature plugs are fitted to the connector. This operation is performed through the opening at the center of the handset. Finally, this opening is closed by the volume control plate which is held in place by two small screws.

Frequency response curves in the diagram above show the performance on a two mile loop in terms of the sound pressure delivered to an artificial ear by a closely coupled handset. A curve of the same circuit and set with a standard (nonamplifier) handset and curves for a 532 type set also are shown. As previously mentioned, the output from the amplifier and standard sets are comparable when the volume control is set near the minimum gain position. The relatively higher



Frequency response curves for the 532 type set and the 500 type set with G6A handset at maximum and minimum gain settings are shown above.

output obtained with the amplifier at the higher frequencies is a desirable characteristic. At maximum output, the sound levels do not reach the threshold of feeling and therefore will not injure a person's ear. The levels are limited by the overload characteristic of the amplifier and by the click reducing characteristics of the 100A varistor shunting the receiver.

Introducing gain in the receiver circuit, or in the transmitter circuit, may cause the circuit to oscillate or "sing." Singing occurs when the volume control is set to provide enough gain to overcome the circuit losses; i.e., when sound actuating the transmitter is reproduced by the receiver and reaches the transmitter at a higher level than the initial sound pressure. Singing does not occur in these handsets if they are well sealed against the user's ear; however, these amplified handsets sing at high gain settings if both the transmitter and the receiver ends of a handset are open acoustically.

The G8A Handset

The G8A handset, a modification of the G6A, is intended for use on telephones located in very noisy locations. Almost everyone, at one time or another, has had trouble using a telephone because of surrounding noises. Noise picked up by the transmitter is annoying to the party at the

far end of the line and, since this noise is also transmitted to the receiver in the noisy location via the sidetone path, it masks incoming speech signals. With normal telephone sets, the party at the quiet end of the line can usually understand the conversation better than the person in the noisy area because the latter automatically tries to talk loud enough to override the noise.

Assuming that the handset receiver cap provides a fairly good fit on the ear, noise that leaks under the cap is not as loud as the sidetone noise in a normal 500 set. Also, noise picked up in the free ear ordinarily causes less masking than noise in the active ear. People using telephones in noisy places sometimes try to improve their ability to hear by putting their hand over their free ear. This gives little improvement except where the surrounding noise is speech which distracts the listener from the incoming conversation.

In noisy locations, unmodified 500 type sets perform quite adequately up to noise levels of about 90 db RAP (Reference Acoustic Pressure). This is about the level of ordinary speech at the transmitter grid. Reception of the incoming speech signal can be improved by covering the transmitter grid to shut out sidetone noise while listening. Reception at both ends of the line can be improved by attenuating the transmitter output about ten db; both transmitted and sidetone signals are reduced. The 500 type sets with attenuated transmitter outputs perform well in ambient noises up to about 100 db RAP. Reception in the noisy location can be improved further by providing gain to increase the loudness of the incoming speech signal. The G8A handset attenuates the transmitter output and amplifies the receiver signal. It improves reception in very noisy locations as much as 25 db over a normal 500 set.

The G8A handset is very similar to the G6A handset. Dashed lines in the schematic of the G8A on page 161 enclose components not used in G6A handsets. Resistors R4, R5, and R6 have been added to reduce the output from the carbon transmitter. Resistor R7 has been added to limit the maximum gain of the amplifier. A switch with two pairs of contacts (a, b, and c, d) has been added to provide two operating conditions. It is mounted alongside the volume control so it can be operated easily without removing the handset from the ear.

In many circumstances the handset is used without operating the switch. With the switch button released, resistors R4 and R5 (in series and in parallel with the transmitter) reduce the transmitter output level about ten db; resistor R7 limits the amplifier gain to slightly more than ten db. Thus, with the volume control set for maximum gain, received speech levels will be increased, transmitted noise levels will be decreased, and sidetone noise levels will be about the same as from a standard type handset. With the volume control set for minimum gain, the incoming speech signal will not differ significantly from that of a normal handset. Outgoing and sidetone noises will be decreased, but outgoing speech levels will approach normal levels if the talker raises his voice ten db as a consequence of being in a noisy place.

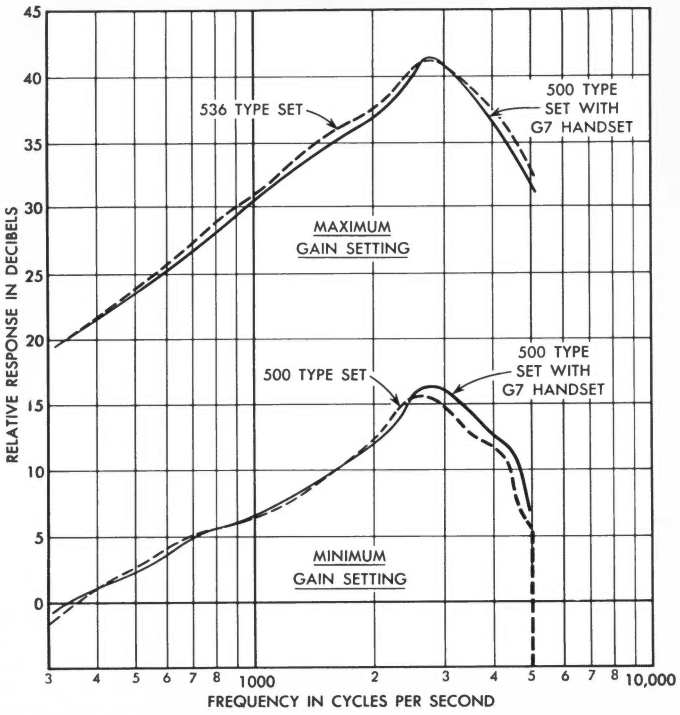
When the switch is operated, contacts a and b are opened and the resistance R6 is in series with the transmitter. Output from the transmitter is reduced a total of about 25 db; sidetone and transmitted noise levels are quite low, and outgoing speech levels may not be loud enough to be intelligible to the distant party but are still loud enough to eliminate the "dead line" effect. Operating the switch also closes contacts c and d, placing a short across R7; the amplifier can then be operated up to full gain as required to make the incoming speech signal intelligible. Reception at very noisy locations can be as much as 25 db better when using the G8 than when using an unmodified telephone set; however, it may be necessary to press the switch during listening periods and release it while talking.

In all situations, the possibility of the set breaking into oscillation (singing) is remote because the transmitter output is attenuated before gain is added in the receiver circuit.

The G7A Handset

The G7A handsets, for persons who cannot speak above a whisper or for those who wish to speak in a confidential manner, differ from G6 and G8 handsets in that the amplifier is used to increase the output from the transmitter. The receiver is connected to the telephone set circuit and operates the same as in nonamplifier type handsets. Basically, the amplifier circuit and the physical assembly of the components are very similar to those of the G6 handset.

As shown by the bottom schematic on page 161, the diodes making up the polarity guard are connected between the network and the carbon transmitter. Speech output from the transmitter is fed directly to the input terminals of the amplifier; i.e., through the volume control to the emitter and through blocking capacitors C2 and C3 to the base of the transistor. The signal output from the transmitter is blocked from the network by inductor L2 which isolates the amplifier input



Frequency response curves for the 536 type set and the 500 type set with the G7A handset at maximum gain settings are shown above. Curves for the 500 type set with and without the G7A at minimum gain settings are also shown.

from the amplifier output. Output signals from the collector and emitter terminals of the transistor are transmitted through the transformer, through blocking condenser C4 and through the polarity guard to the telephone network transmitter terminals R and B.

Typical response versus frequency curves for maximum and minimum gain settings for the G7A handset are shown above with curves for the 536 and 500 type sets. As indicated by the curves, the output at minimum gain is comparable to that of a nonamplifier type handset, while the output at maximum gain is increased about 20 db for low speech levels and corresponds to the maximum gain obtained from the 536 type set. As the input speech level is increased, the amplifier overloads. The maximum output level delivered to the line is about two milliwatts.

The number of these amplifier type handsets now being manufactured is much greater than had been anticipated, indicating that they are providing needed services for many more customers than the sets they supersede. Also, features of these designs are being used in other apparatus to provide a wider variety of customer services.

New Type of Hig

A new type of light-weight, high-strength laminate and a process for deep drawing this material into a variety of shapes have been developed at Bell Telephone Laboratories.

The laminate—two aluminum sheets bonded to a solid polyethylene core—appears well-suited for many commercial applications. These might include airplane and ship panels, small boat hulls, luggage, automobile body parts, and housings for portable equipment. The Bell System is considering the laminate for telephone equipment housings.

Unlike other reinforced plastic laminates, this new composite material can be welded. It also can be adhesively bonded to many other materials, and it can be riveted, bolted, punched, and sheared. Though it is comparatively inexpensive to produce, its flexural properties in relation to its weight are superior to most widely-used commercial materials. For example, a four-pound laminate sheet would deflect the same amount under the same bending moment as would a 10-pound steel sheet of equal width.

Karl Pohl and Arthur Spencer conceived of and

Bell Laboratories' new aluminum-polyethylene laminate, a polyester glass mat laminate, and cold-rolled steel are shown left to right. These strips are of the same length and width and support equal loads. The thickness of each strip varies in relation to its specific gravity so that all weigh the same. At the bottom of the photograph are samples of the aluminum-polyethylene laminate that have been deep drawn.