COMMUNICATIONS

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LIMITING AMPLIFIERS

By **JOHN P. TAYLOR**

SOME MONTHS AGO one of the larger broadcast equipment manufacturers (Western Electric) introduced a speech-input amplifier designed to provide automatic compression of program peaks. Recently other manufacturers have announced more or less similar units. The interest in, and flood of orders for these equipments, indicates that they are likely to become a broadcast fixture. The manufacturers, in a burst of conservatism, started out by referring to units of this type as "program" amplifiers. However, an industry noted for its realistic nomenclature has irrevocably dubbed them "limiting" amplifiers. Nor does this seem unjustified, for a study of the three units announced to date indicates that they are built, essentially, around the limiting feature—with secondary considerations—as, for instance, their use in place of the usual "program" amplifier—falling pretty much under the heading of making virtue out of necessity.

Recognition of the possibilities of applying automatic gain control to transmitter circuits is far from being a new development. More or less successful circuits to this end were devised some ten years ago. And a limiting amplifier practically duplicating the operations of those now offered for broadcast purposes has been in regular use in motion-picture studios for several years. Why the practical application to broadcasting was so long delayed is something of a mystery. That there was, and is, a demand for such a device is well-proven by the fact that, in a period of a few months, more than half the stations in the country have placed orders for these units.

No doubt part of the reluctance to introduce such a device can be attributed to the hush-hush attitude toward "compression" which formerly prevailed. There was a time, and not so long ago, that the very mention of the subject was almost a misdemeanor. However, this

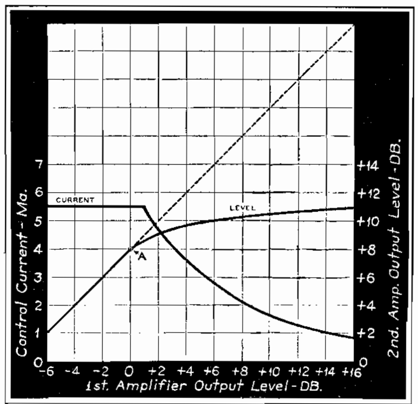


Fig. 1. Operating characteristic of the Type 110-A amplifier.

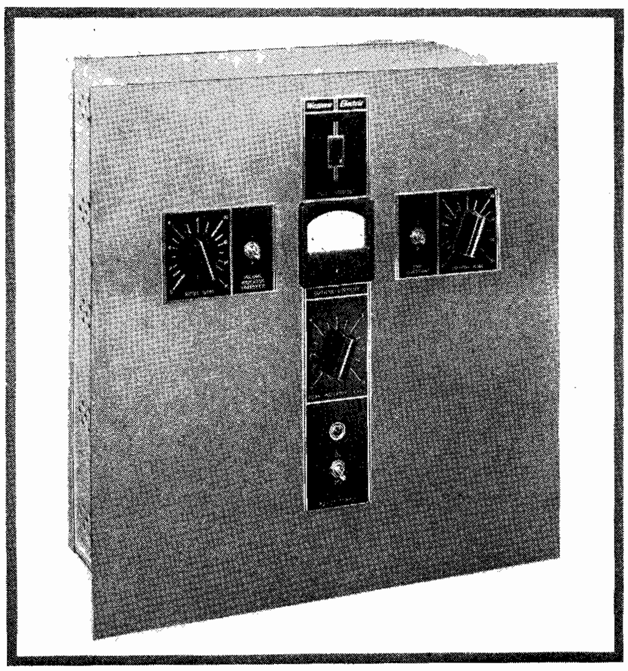


Fig. 2. Front view of 110-A unit. Controls include level adjustments, peak-flash lamp, and power, VI meter and time-constant switches.

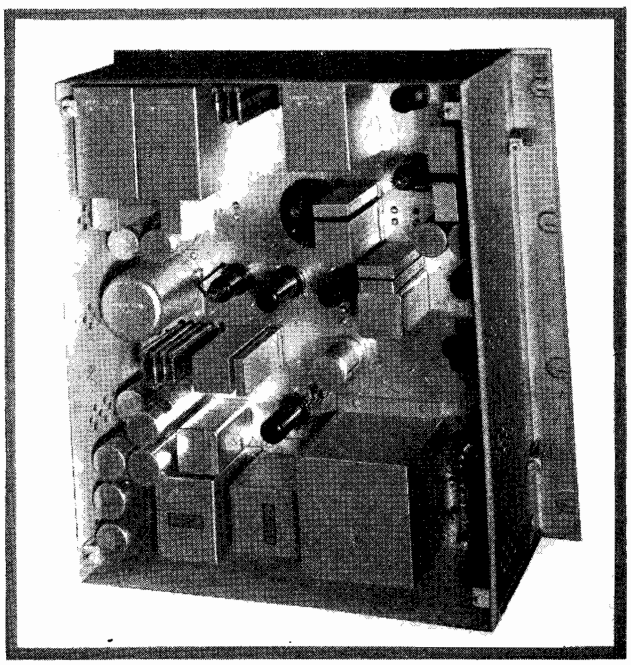


Fig. 3. Rear view of 110-A amplifier with cover removed. Mounting of tubes and main components can be seen. Terminals and wiring are covered.

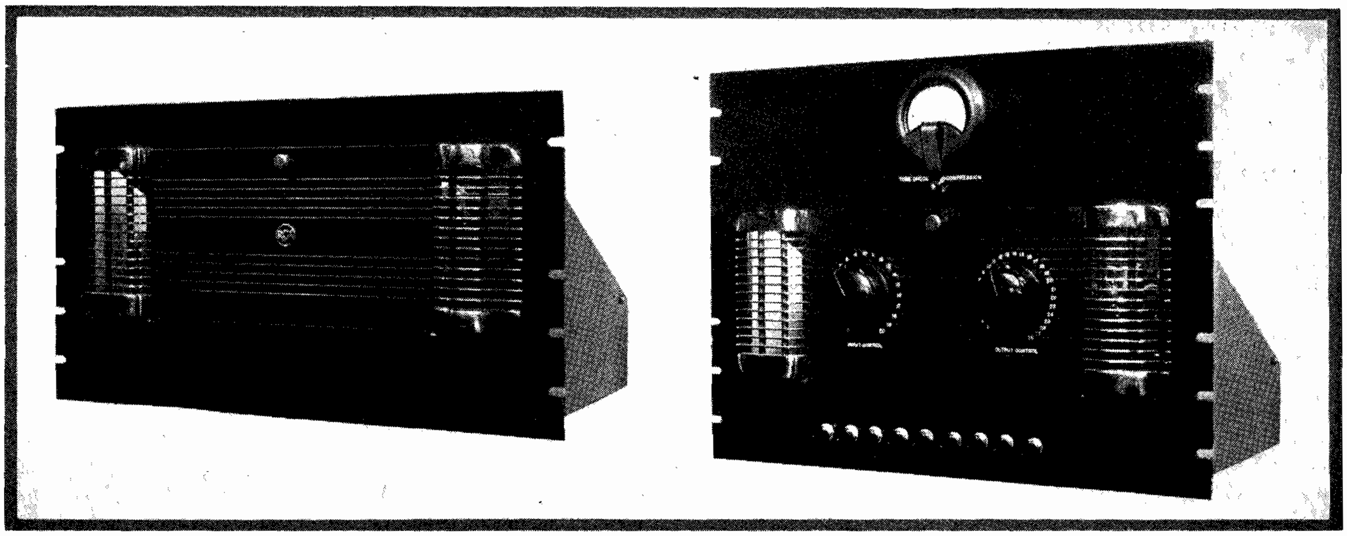


Fig. 5. Front views of the 96-A amplifier and power-supply unit.

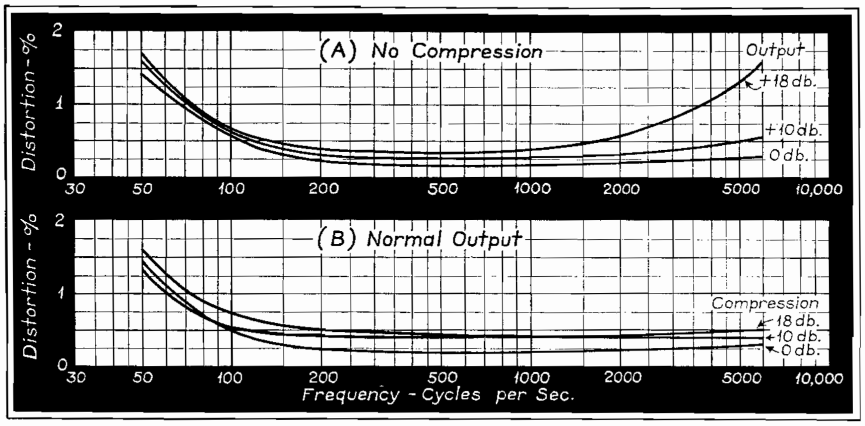
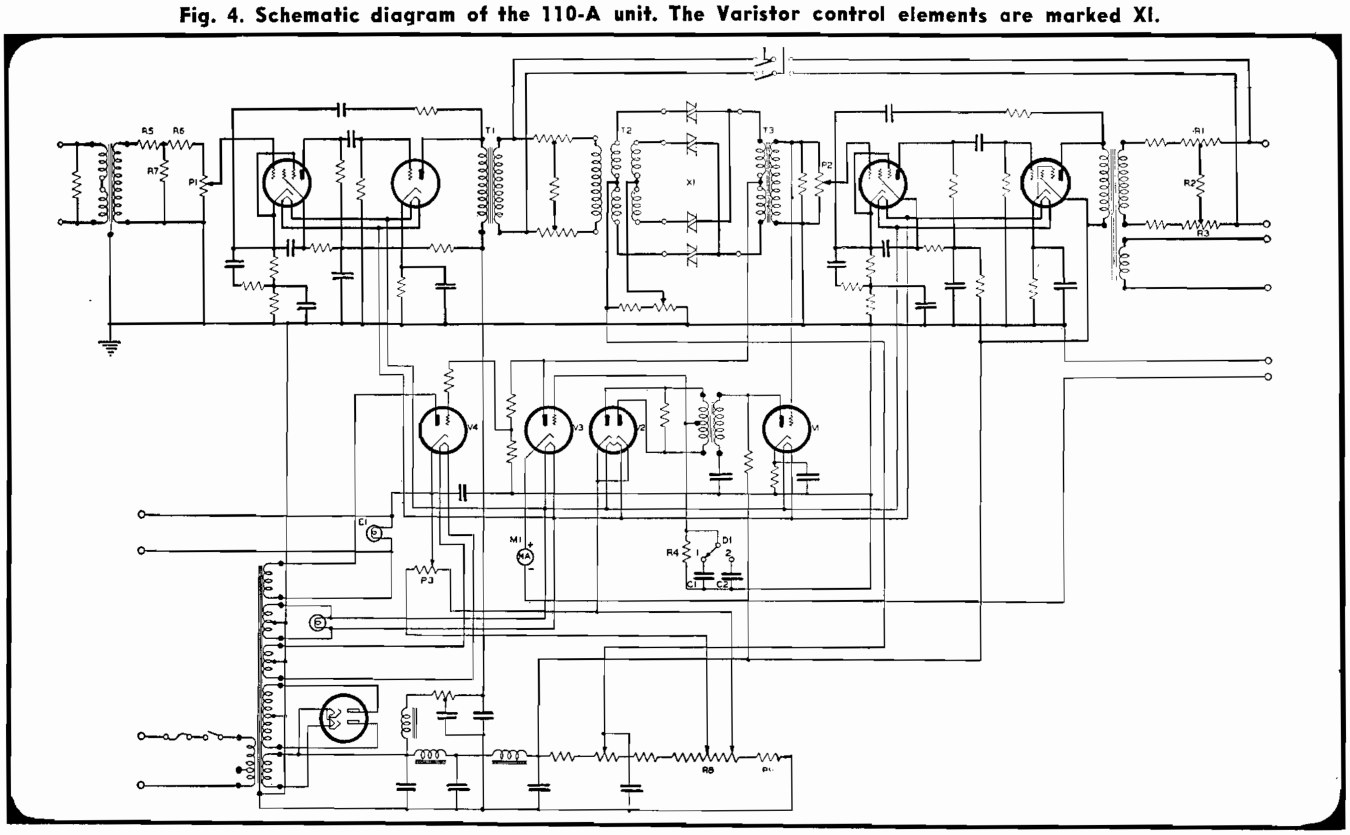


Fig. 8. Performance of 96-A amplifier. (A) Distortion at no compression. (B) Distortion for various degrees of compression (0 db output level).

has gradually given way to a more common-sense viewpoint of the problem. After all, where acoustic levels ranging up to 90 db must be fitted into transmitter receiving systems limited to 50 db or less, compression—voluntary or involuntary—is inescapable. Either the modulating degree is greatly reduced, and part of the low-level range thereby lost in the background, or else high levels are ridden down and lows brought up (by the control operator) until the spread approximates the transmissible range. Allowing for differences of opinion as to degree, there seems to be general agreement that the latter course is preferable. The point of this is not to

Fig. 4. Schematic diagram of the 110-A unit. The Varistor control elements are marked XI.



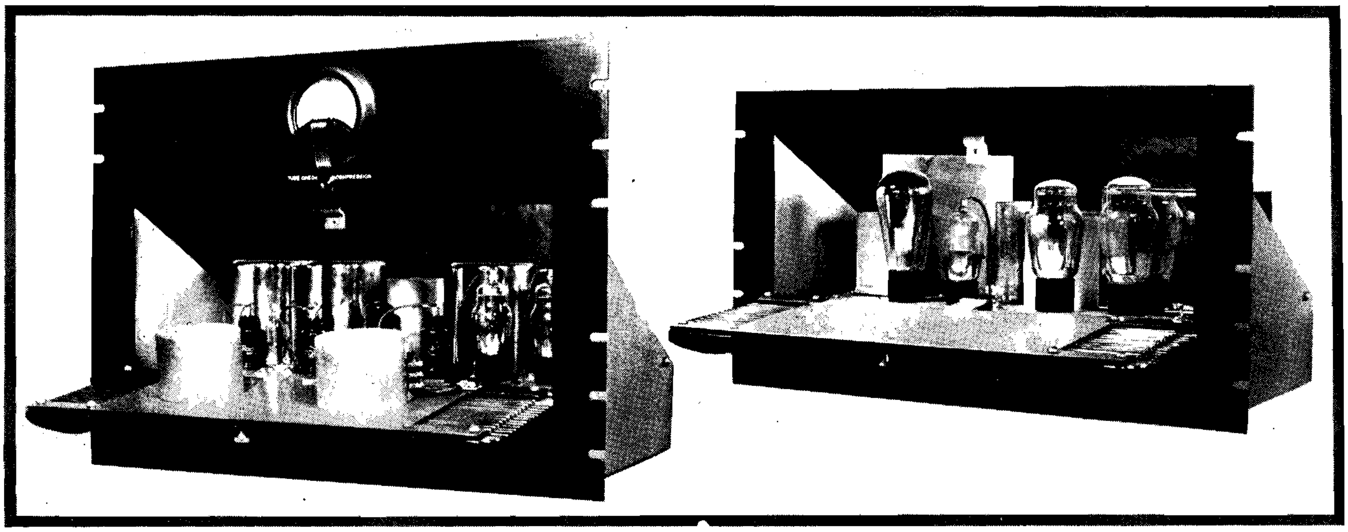


Fig. 6. The 96-A amplifier and power supply with front doors open.

make a direct comparison between the operations of the control-room operator and that of the limiting amplifier—since there is, as noted below, an essential difference—but simply to bring out the fact that now there is no objection to compression per se.

THE IDEA

At first glance the operations performed by a limiting amplifier seem much like those of the studio control operator in riding gain. The only actual similarity, however, is in that both entail compression of the volume range. The function of the control operator is to manually adjust the gain in accord-

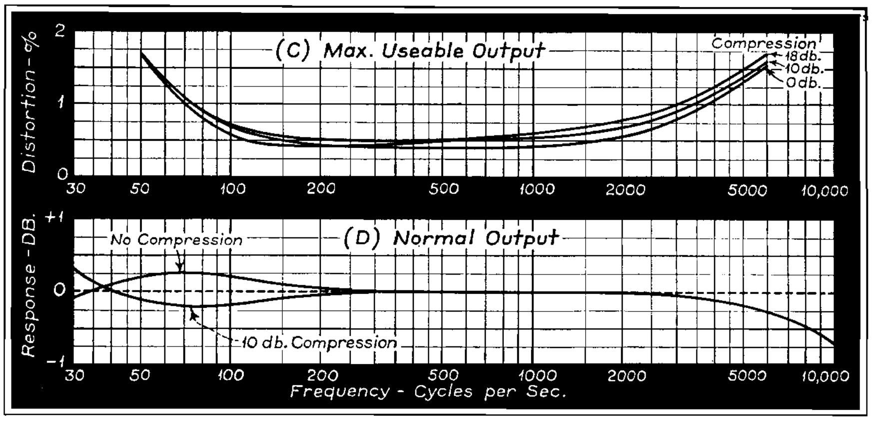
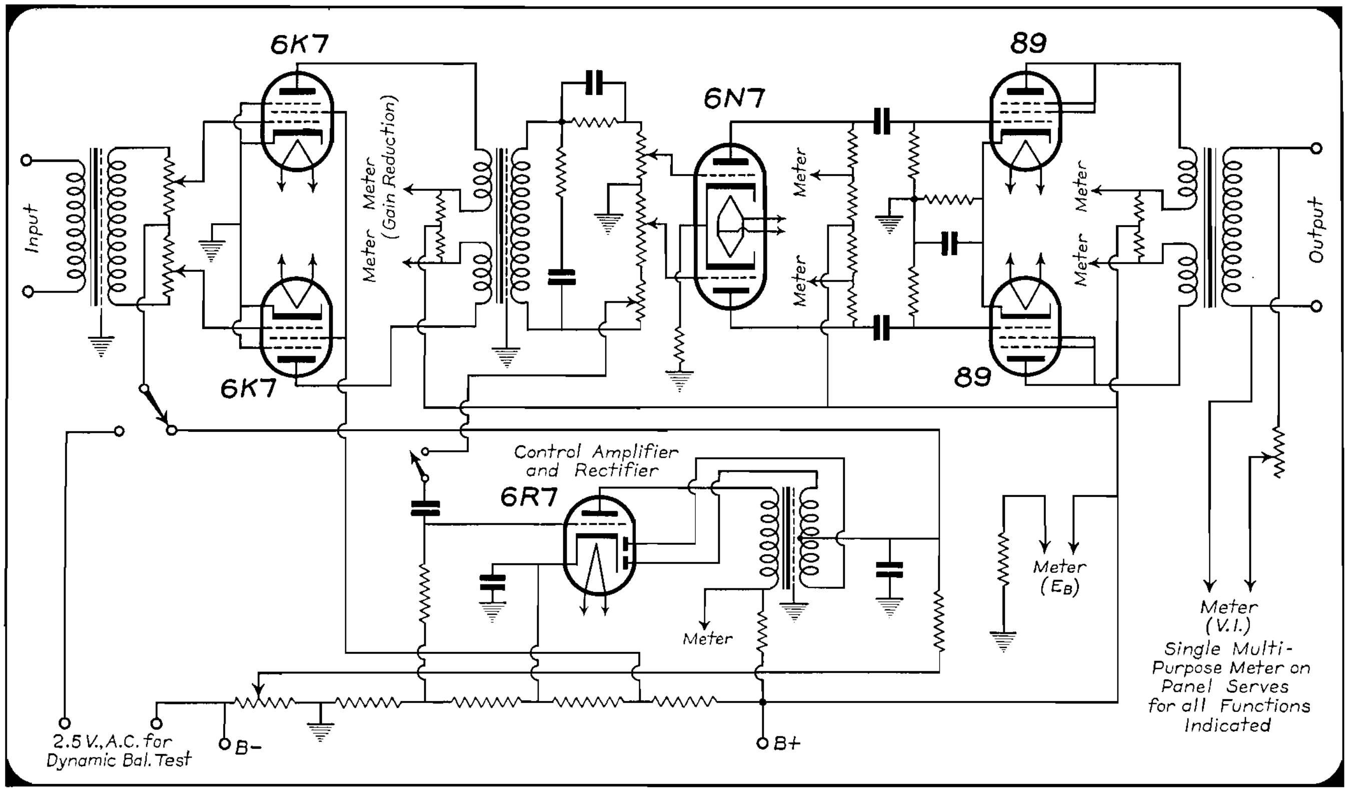


Fig. 8. Performance characteristic of 96-A. (C) Distortion for various degrees of compression (plus 18 db output level). (D) Frequency characteristic.

Fig. 7. Schematic diagram of the 96-A amplifier. The amplifier proper composes 3 push-pull audio stages.



ance with the average level of the program. He can raise a low passage, or reduce a loud one; but he cannot, as a rule, act quickly enough to cut down loud peaks of short duration. If he is adept in following the score, or has had the benefit of many rehearsals, he may indeed anticipate some of these. But most operating is not accomplished under such conditions, and even when it is there will remain occasional peaks not suppressed as desired. Hence, if the effects of overmodulation—carrier shift, distortion, adjacent-channel interference—are to be avoided, it is necessary to keep the average modulation sufficiently low that these peaks do not greatly exceed 100 percent modulation. But, since these peaks may represent levels several times the average level, such operation necessarily means very ineffective use of the available power. It is this situation which the limiting amplifier is intended to improve. The method is to provide a gain reduction system which, coming into play at high audio levels, automatically reduces the gain of the system and thereby keeps peak levels within a predetermined limit. Properly used, this allows the average modulation to be stepped up to something like half again as much—say from 30 percent to 45 percent. Output at the receiver is, of course, proportionately increased.

THE OPERATION

It will be well to note that while the operation of the limiting amplifier is essentially that of an automatic gain control system, it is a control which functions only at high levels. At all ordinary levels it is inoperative. In this respect it may be likened to the "delayed a-v-c" action used in some receivers. In Fig. 1. is shown a curve which illustrates this operation. It should be noted that this is a plot of audio levels—inputs, to the control stage, vs. output—rather than the usual dynamic characteristic, with which it may be easily confused. Looking at this curve, it will be seen that up to a preset point (marked A on the curve) results in a corresponding increase in output. Above this point, however, only slight increases in output occur for even very large increases in input level. If the input is adjusted so that this point ("A" on the curve) corresponds to ordinary peak program levels, and the output adjusted so that, at this same point, the transmitter will be modulated up toward maximum (say 80 percent), then excessive peaks, giving inputs above this, will cause the gain reduction system to function, with the result that a graduated compression will be applied and likelihood of overmodulation practically eliminated. At the same time, however, the operation at all levels below this predetermined point is unaffected. Moreover, this type of compression—which is comparatively severe—must be applied only to peaks of the short excessive-level type; it should never be used to reduce gain on high passages of continued duration. Thus the limiting amplifier in no way takes the place of the control operator. It does supplement his efforts, and helps him to achieve better results. But any idea that it will replace or eliminate "gain-riding" is erroneous and should be carefully eschewed.

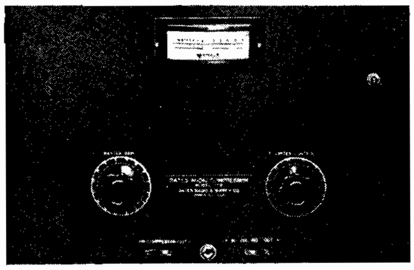
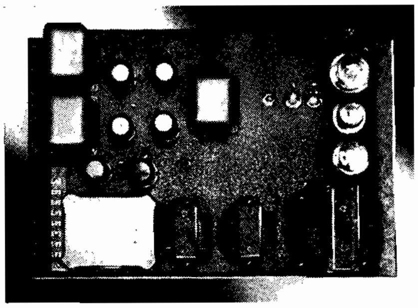


Fig. 9. Front view of the Type 17-B audio compressor.

Fig. 10. Rear view of the Type 17-B audio compressor.



THE VARISTOR TYPE

While the three standard types of limiting amplifiers so far made available are quite similar as to characteristics, and almost exactly so as to mode of application, they show a very interesting contrast in the manner in which the desired gain reduction is obtained. The Western Electric Type 110-A amplifier, which was the first of these equipments to make its appearance—and which is shown in Fig. 2 and Fig. 3—depends for its essential operation on the use

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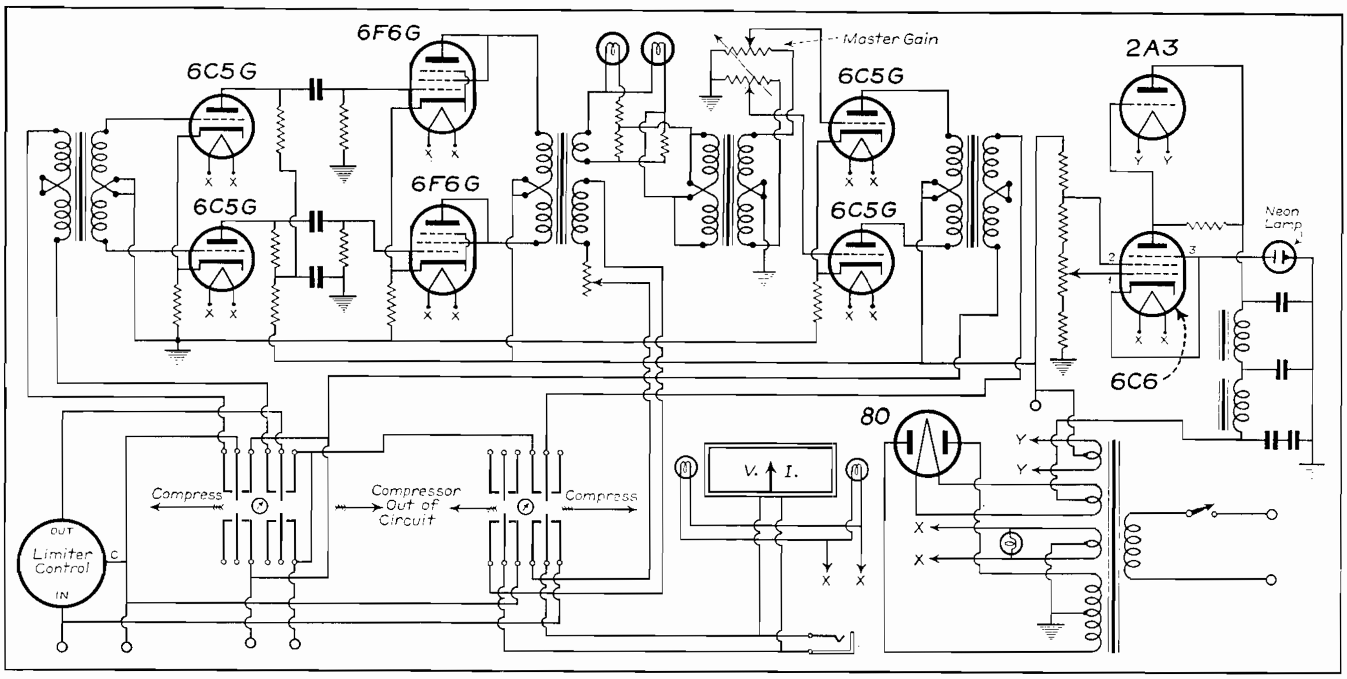
Fig. 11. Schematic diagram of the 17-B audio compressor.



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of Varistor control elements. The resistance of these varies inversely with the d-c voltage through them. The placement of these elements, of which there are four altogether, is shown in Fig. 4, which is the schematic of this amplifier. Referring to this diagram, it will be seen that the audio circuits (heavy lines) compose a two-stage input amplifier, followed by the gain adjustment network, and this by a two-stage output amplifier. The control circuit operates as follows. An amplifier V-I (6C5G) feeds a full-wave rectifier V-2 (6H6G), which rectifies the audio wave and applies the resulting d-c voltage to the grid of the control tube V-3 (6C5G). The bias supplied the latter determines the point at which the compressing action begins. When rectified signal voltage exceeds this bias the plate resistance of the control tube is increased, the potential across the Varistors is reduced, and the loss through these is correspondingly increased. The use of four Varistor elements in a series-parallel arrangement keeps the terminating resistances constant.

THE TUBE TYPE

The RCA Type 96-A amplifier (shown in Figs. 5 and 6) depends for its operation on the variable-mu characteristic of tubes of the remote cut-off type. Looking at the schematic of this amplifier (Fig. 7) it will be seen that the amplifier proper consists of three push-pull stages. The gain control is exercised in the first stage. The method of operation follows. A portion of the audio output of the first amplifier stage is tapped off the secondary of the interstage transformer and fed to the triode section of a 6R7. The output of this section of the tube is rectified by the diode section. The resultant d-c voltage appears across a resistance in series with the bias voltage supplied the grids of the first-stage tubes. The resulting increased bias moves the operating point of these tubes further negative, i.e., to a point on the i_p-e_g characteristic having a lesser slope, and thereby reduces the gain of the system.

THE BRIDGE TYPE

Still another method of obtaining compression is illustrated by the Gates Type 17-B audio compressor (shown in Figs. 9 and 10). While the information on this unit has just been received, and no reports on its performance in the field are yet available, the method of operation can be understood by ref-

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erence to the schematic diagram (Fig. 11). The unit consists, essentially, of a two-stage push-pull input amplifier, followed by a control network, and this in turn by a single-stage push-pull output amplifier. The control network makes use of an arrangement in which a series-bridge circuit, with lamps as control elements, is utilized to effect the desired compression. A regulated-type power supply provides the necessary stability. Since this unit is intended to be used in conjunction with an external amplifier, gain provided is considerably less than in the two previous equipments.

It will be immediately evident that one of the most important characteristics of these limiting amplifiers will be found in the time required for the gain reduction to take hold, and, to a somewhat lesser extent, for removal of the loss after the program has returned to normal levels. These time constants must necessarily represent a compromise. If the action is too rapid the gain control may try to follow the cyclic variation at low audio frequencies—producing what one engineer has called "echoburps." On the other hand, if it is not sufficiently rapid in application, the transmitter may well be overmodulated before the gain reduction can take effect. The best approach to a solution seems to be to make the action take hold relatively quickly, but to release quite slowly. This can be compared to the operator who, caught napping on a sudden peak, makes a quick lunge to reduce his gain, then returns it gradually to normal again. Even so, there is not particularly good agreement as to the best time-action—at least in so far as the published characteristics are concerned. For the two equipments on which they are available these are:

	Time for reduction	*Time for release*
110-A Amplifier		
Position 1....	.020 sec.	.250 sec.
Position 2....	.010 sec.	.125 sec.
96-A Amplifier.	.001 sec.	7.0 sec.

If these figures represent comparable methods of measurement, it is hard to account for the rather surprising differences, particularly since both equipments are said to have been given exhaustive tests in actual use.

Of the arguments given, at one time or another, against limiting amplifiers, the only one warranting serious consideration—at least from a practical viewpoint—is that of the possible introduction of distortion. It has been rather widely-held that low-frequency distortion must necessarily be excessive. In view of this, the curves given in Fig. 8 are of considerable interest. These are the characteristic operating curves of a typical 96-A amplifier—taken in the usual manner for speech-amplifying equipment. Looking first at Curve (A), which is with no compression, it will be seen that at normal output level (0 db) the distortion content figure is very good—except that at the low end it rises to 1.5 percent at 50 cycles, which, however, is still hardly objectionable, although not quite equal to that of the best of recent program-amplifier designs. Observe now Curves degrees of compression, at normal and maximum outputs, respectively. Noting that the small differences shown for various compression levels are close to the limit of accuracy, it can be concluded that there is no real increase in distortion as compression is applied. This certainly refutes the argument in so far as this particular unit is concerned. Of course, these characteristics can show only what might be termed the "steady-state" distortion. The transient distortion is quite a different problem. But then, very little is known of the transient distortion introduced by even the commonest of broadcast units.

OPERATING LEVELS

In all of these three amplifiers the actual level at which the gain reduction is introduced is fixed. The necessity of this is obvious from the difficulty which would be encountered in trying to make variable circuit elements of this type operate satisfactorily at various levels. The limitation which would otherwise result from this is reduced by provision of input and output amplifiers having a wide range of gain. The 96-A and 110-A amplifiers will operate with inputs of the order of —35 db and furnish outputs of up to approximately +20 db. Since both inputs and outputs are separately adjustable, these amplifiers may be used in almost any way desired within the range of these levels. Because of this, and since their obvious point of application is at the transmitter, they may well be used in place of the so-called "program" or "line" amplifiers which are ordinarily employed to raise the incoming line levels to the level required to feed the transmitter. The 17-B requires a minimum input of —10 db and furnishes a maximum output of +6 db. It is intended to be used in conjunction with a program amplifier previously installed, or with a fixed-gain amplifier which the manufacturer makes available. Such a combination will be approximately the equivalent, in so far as gain and application are concerned, of the larger equipment.