P.A. LOUDSPEAKER PRINCIPLES AND PRACTICE

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How to select the proper reproducer to achieve best sound coverage for public-address use. Speaker connections, the constant-voltage system, and power requirements are covered.

THE function of a public-address system is to deliver an audible message either to a particular individual or to a group of individuals. The choice of a loudspeaker, or speaker system, will be based not only on the number of people who must be reached but also upon the environment in which these particular people are expected to receive the information or message.

SECTION 1—THE REPRODUCER

The p.a. family of reproducers can be broken down into specific groups, such as relatively small paging and talk-back speakers, larger higher power projector trumpets with spatially uniform sound coverage, wide-angle horns for contouring the reproduced sound pattern into one preferred plane, and column speakers (or line radiators) for combined high-directivity control and extended frequency response.

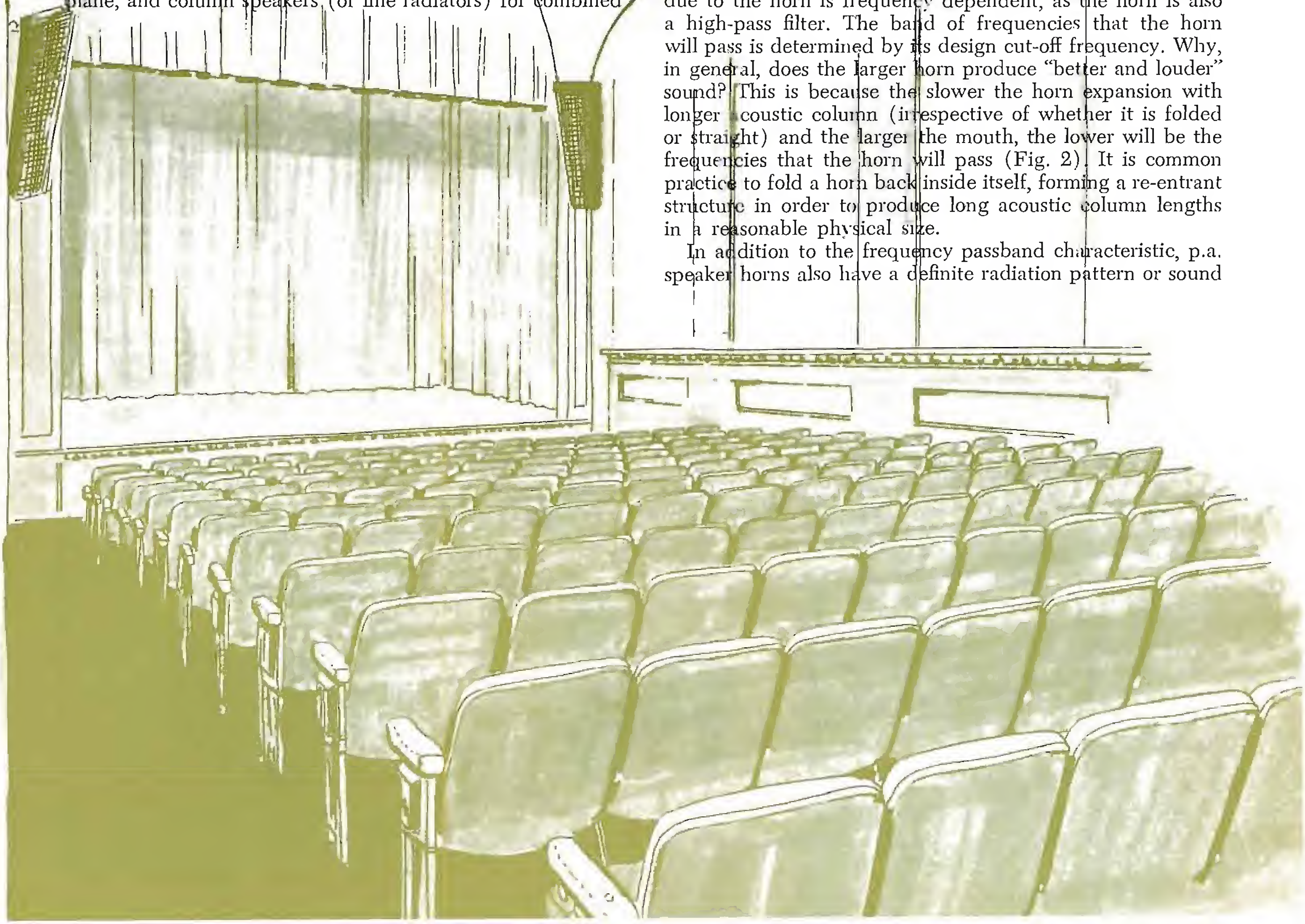
With the exception of the column speakers, p.a. reproducers use compression-driver, horn-loaded types. This design assures high efficiency of conversion of electrical power into acoustic power, on the order of up to approximately 35 to 50 percent in some cases.

The Horn—An Acoustic Transformer

A horn is a tapered acoustic transmission line, or an acoustic transformer, which provides an effective impedance match between the driver unit (the source of the sound) and the air around it. The mechanism by which this takes place is illustrated in Fig. 1.

The improvement in the radiation efficiency of the system due to the horn is frequency dependent, as the horn is also a high-pass filter. The band of frequencies that the horn will pass is determined by its design cut-off frequency. Why, in general, does the larger horn produce "better and louder" sound? This is because the slower the horn expansion with longer acoustic column (irrespective of whether it is folded or straight) and the larger the mouth, the lower will be the frequencies that the horn will pass (Fig. 2). It is common practice to fold a horn back inside itself, forming a re-entrant structure in order to produce long acoustic column lengths in a reasonable physical size.

In addition to the frequency passband characteristic, p.a. speaker horns also have a definite radiation pattern or sound



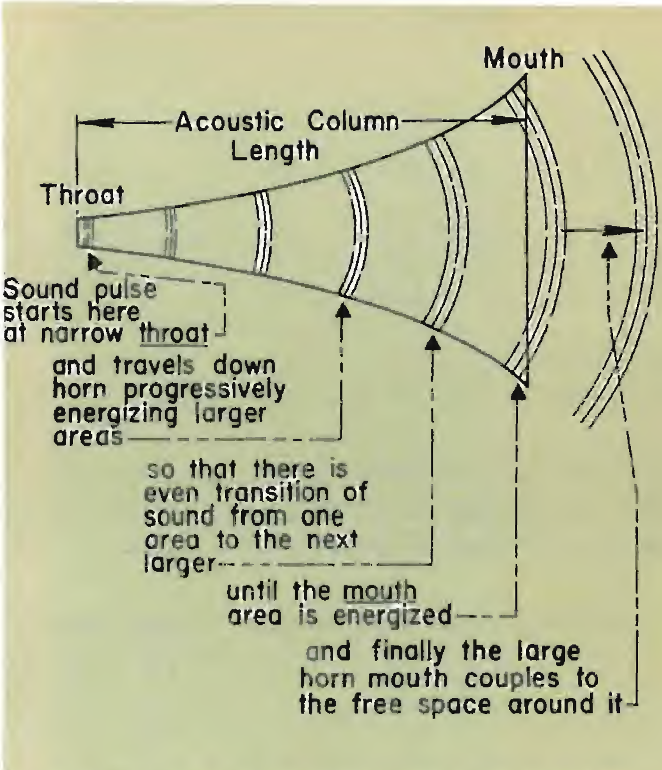
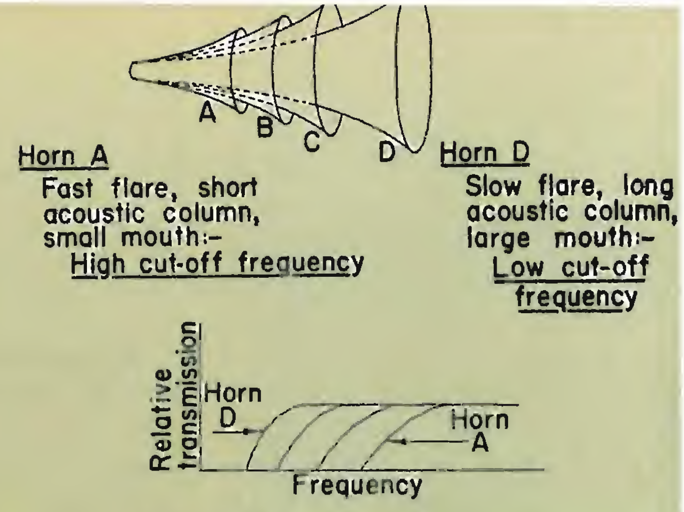


Fig. 1. Wave progression down a horn, which acts as an impedance-matching device between driver at throat and free space.



Air-Column Length	Mouth Dia.	Cut-off freq.	Dispersion
6 1/2'	32"	85Hz	65°
4 1/2'	26"	120Hz	75°
3 1/2'	21"	150Hz	85°
2 1/2'	16"	200Hz	95°

Fig. 2. The long, large-mouth horn has a lower cut-off frequency and less dispersion (more directivity) of sound.

dispersion. Not all horns have the same spatial distribution, even though they all may be of round or uniform cross section. As in a cone speaker, the larger the radiating piston (or mouth), the sharper the beam for a given frequency.

We can increase the dispersion, if required, by putting two (or more) horns side by side, arranged in an arc. There are applications where wide-angle coverage is desired from a *single* horn, rather than a cluster of horns; hence, acoustic structures have been designed to provide such wide-angle dispersion. It is also possible to contour the last section of the horn — usually called the "bell"—which does the actual radiating, in such a fashion that the sound pattern is no longer symmetrical about a given axis but is concentrated in and spread out over one plane and minimized in the other. Two such horn structures are shown in Fig. 3. Another means of producing the wide-angle sound is with the double-mouth structure shown.

When dealing with wide-angle p.a. speaker systems, we must pay particular attention to a non-horn system — the column speaker or linear array. Such columns are made up of a multiplicity of cone speakers, usually stacked vertically, as illustrated in Fig. 4. The pattern of radiation for a column speaker is one where wide-angle distribution is obtained in the *horizontal plane* through the center of the vertical axis as shown. Its distribution in the vertical plane is, however, severely restricted and highly directive.

The Driver Unit

The driver unit, so-named because it drives or energizes the horn, is remarkably small considering the amount of power it can handle and for the amount of acoustic power it can develop in conjunction with a well-designed acoustic horn.

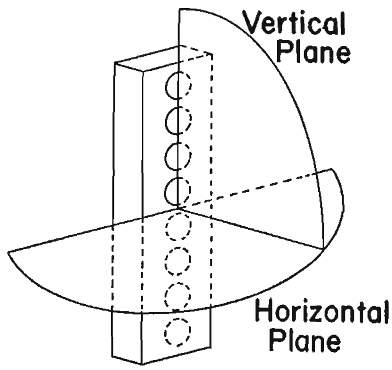
One often hears the horn system referred to as being

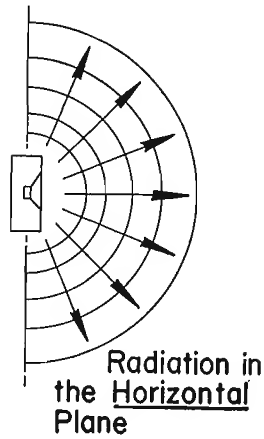
Fig. 3. Standard horns at (A) and (D) produce symmetrical sound patterns. Horns at (B) and (E) have been specially shaped to produce a greater horizontal spread of sound when mounted as shown. Dual horn at (C) has same effect.

energized by a *compression* driver unit. The compression is the sealed rear volume behind the diaphragm in the driver unit. Rather than acting as a deterrent to diaphragm motion, this stiff rear cushion actually improves the performance of the system. This rear acoustic stiffness acts as an acoustic capacitance and, in a properly integrated driver-horn combination, the capacitive reactance balances out the inductive reactance of the horn that loads the front of the diaphragm. As a result, the system becomes totally resistive and most efficient.

Driver units come in various power ratings from 5 watts up to 75 watts for standard, commercially available systems. The size of the voice coil, including wire size and coil diameter as well as the cements that hold the voice coil together, determine the electrical power that can be fed into the coil before it fails electrically. The design of the diaphragm and its edge suspension will determine to what degree the diaphragm can be vibrated mechanically before its suspension ruptures or its main body breaks up. Thus, power handling capability depends on electrical as well as mechanical considerations.

Driver units have much in common and yet they may be made to differ widely, *and intentionally so,* in performance. Some of these important variables are power-handling capacity, conversion sensitivity (related to magnetic circuit efficiency), frequency response (related to diaphragm and head design), size, whether parts of the unit as a whole can be replaced, and built-in transformer facility. Fig. 5 pinpoints all of the components going into the construction of a well-designed driver unit for public-address applications.





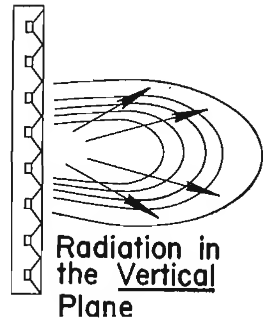


Fig. 4. A line of cone speakers forms an in-line or column array which concentrates sound vertically, allowing it to spread horizontally.

SECTION 2—SOUND COVERAGE

Despite the many types of p.a. speakers, there are two common factors that dictate what type of unit will best serve a given application. The first is the acoustic environment into which the sound is to be projected; this includes size, reverberation characteristics, and expected noise levels. The second factor is listener distribution.

Symmetrical Long Throw

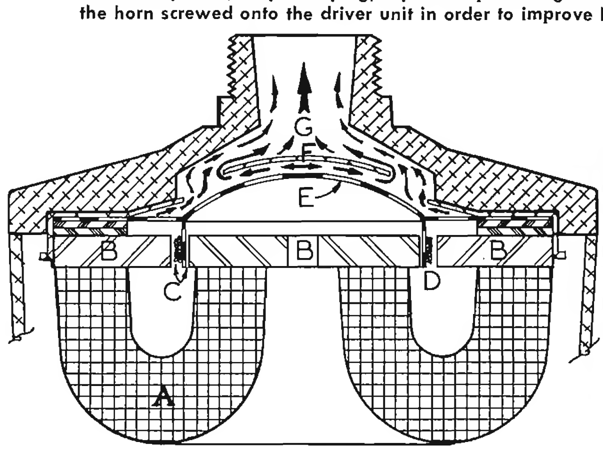
As previously mentioned, the standard round horn has a symmetrical distribution pattern about its central axis with maximum energy directly on the axis. Such symmetrical horns are, therefore, to be preferred for either long-throw sound projection or short-throw penetration. The former means putting as much energy as possible as far ahead and in front of the horn, while the latter is concerned with getting a message directly into a nearby spot by penetrating into moderate or high-noise-level spot areas.

To illustrate: several hundred people may be gathered in an assembly area, such as an open field, to listen to a political speech. Such a group usually gathers as near on-center to the speaker's platform as possible. They would almost certainly form a lobed-out pattern so that they could see the speaker as well as hear him. Such a distribution lends itself ideally to the pattern of coverage obtained from a symmetrical horn for that horn lays down its most effective sound pattern directly along its axis. For such long-throw projection, one usually sees horns of the larger type used. The advantage of such a large horn is that the lower cut-off frequency extends the reproducible band of frequencies down into the area where most of the voice *power* lies. This means that greater sound pressures are obtained farther away from the horn mouth.

But, how about the middle and high frequencies governing articulation? Here we benefit from the fact that this horn has a large mouth which exhibits strong directional characteristics, especially at the frequencies in question. We thus achieve more projected voice power (lower band) with more articulation (high band) beaming riding on top of the power part of the spectrum. The end result is long-throw forward projection for the large symmetrical horn.

It may come as a surprise to learn that it is often easier to overcome a high noise level with a small, medium, or low-power penetrator than with a larger, more powerful projector. In this manner, we are enlisting the aid of the "6-dB increase

Fig. 5. Internal construction of compression driver unit along with photo of typical driver. A palate, or phase plug, equalizes path lengths from the diaphragm into the horn screwed onto the driver unit in order to improve high-frequency response.



A —Magnet, which energizes
B-B-B —magnetic circuit, in which
C —magnetic gap is bridged with magnetic flux.
D —Voice-coil field reacts with gap field, moving
E —the diaphragm, which produces sound waves against palate
F —through whose aperture equal path lengths of sound reach head chamber
G —from which path-corrected waves are transmitted to horn.

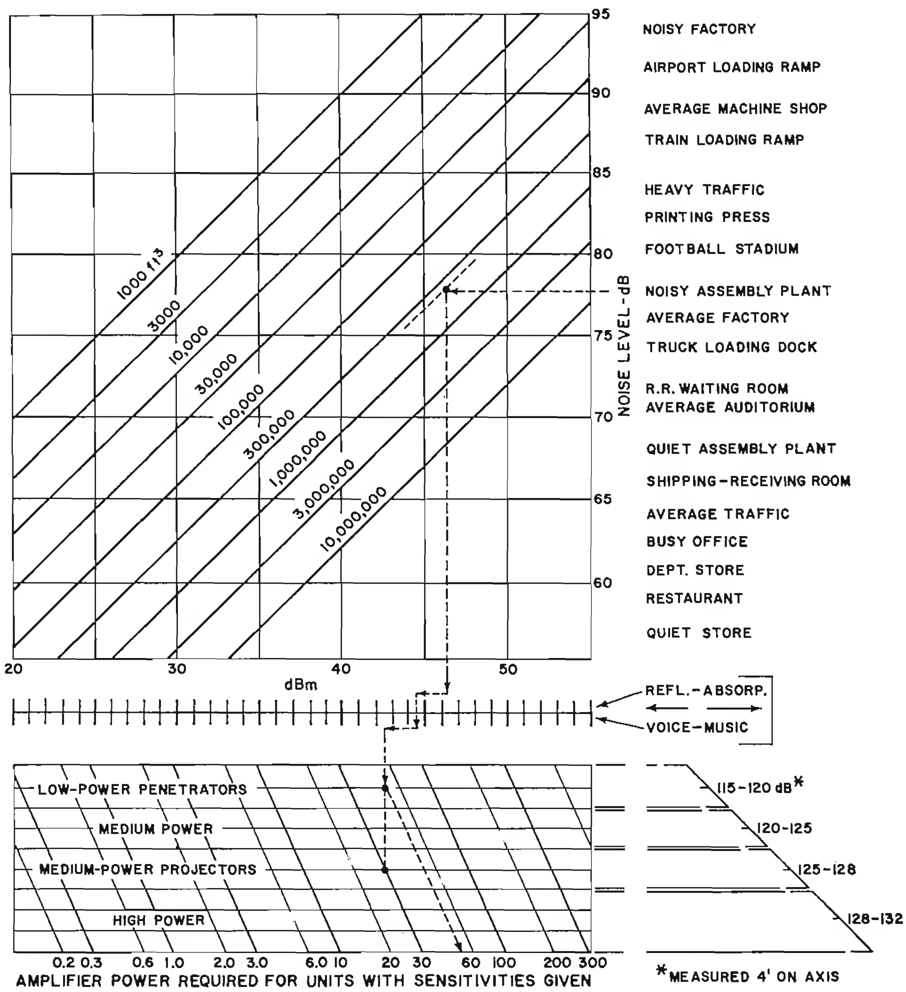


Fig. 6. Acoustic system design chart showing approximate power requirements.

with halving the distance" law, as will be described below.

Consider a high-power loudspeaker projector that, for a given power input, produces a sound intensity of 80 dB, 80 feet away from it. Now place a lower power projector in the same location; for instance, one that will safely take half the power (-3 dB) of the larger one and, moreover, because of the smaller magnetic circuit may be less efficient. Assume that the smaller unit can produce only 70 dB sound intensity at the same distance. Now move the smaller unit toward the listener by 40 feet (halving the distance) and we gain 6 dB in sound intensity. Move it forward another 20 feet (again halving the previous distance) and we gain another 6 dB. Finally, move the reproducer forward 10 feet more (half of 20) and we are able to gain still another 6 dB. We have gained a total of 18 dB over the original sound intensity at that reference point; instead of 70 dB, we have 88 dB at the listening location. All we have done here is to move the reproducer closer to one group of listeners, but to cover a large group of listeners spread over a wide area we will need many such units distributed over the area.

A distributed sound system, consisting of many small speakers placed close-in at the noisy areas, will provide better penetration into those areas than one larger speaker placed far away with the hopes of covering one large area. Such a distribution system is useful, for example, at a railroad or subway platform where the noise of the incoming train may, at times, be almost deafening high. One powerful loudspeaker at one end of the platform will not do the passenger at the other end of the platform any good when the engine or cars are clattering noisily by. However, a number of smaller penetrators spaced rather close together will ensure better transmission of the station master's message.

Distributed systems utilizing small penetrator speakers may also be employed to provide smooth *uniform low-level* coverage in relatively quiet areas. Consider a large warehouse, or a stockroom of considerable size where communications are required to stock clerks or other people working in the aisles between stacked cartons, shelves, or bales. One large, powerful projector placed somewhere in such an area would only blast the nearby working areas and its message would be completely washed out and absorbed by the nearby stock material; little sound would get to the major parts of the warehouse. Many smaller units strategically placed over the aisles (not necessarily one per aisle) would carry the message equally well to all parts of the working area.

Special Features

Of equal advantage with a multiple system of smaller units is that they may function as "talk-back" units if the amplifier electrical system is arranged for such operation. Many man-hours are saved and customer service is improved when "talk-to" and "talk-back" facilities are incorporated in a simple communications system. For such systems the smaller horn units make excellent on-the-spot message projectors, while because of the sound collecting properties of the horn aided by the heavy magnet structures, such units make very sensitive distant pick-up microphones for "talk-back" purposes.

Highly reverberant areas pose many problems. If reverberation is excessive, the p.a. system will be difficult to understand. If we can keep the sound out of the live areas, such as the hollow hard ceiling spaces or the hardwood floor of a basketball court, then we effectively minimize the detrimental reverberant sound. A large number of directional, wide-angle horns may be especially helpful under these particular conditions.

An Acoustic System Chart

A general chart, Fig. 6, may be prepared correlating factors of room size, room reverberation, ambient noise, and sound intensities necessary for either speech or music, with the required electrical power. This chart cannot be absolutely accurate but it can serve as a guide.

To illustrate its use, let us assume we have a fairly noisy assembly plant, 325,000 cubic feet in volume, that requires a p.a. system. We draw a line, as shown, horizontally to meet a diagonal at about 325,000 cubic feet. Assume the building to be a cinder block and glass structure, which is quite live. We drop down vertically to the horizontal reverberation-adjust line. Since the area will be quite live, we move to the left into the reverberant or reflective area by two units (representing about 2 dBm. If only voice transmission is required, we shift to the left by two units (about 2 dBm).

For the area considered, which may be made up of distributed spots of high noise levels, let us choose a distribution of small, low-power penetrators. We drop our vertical line down to meet the center of the low-power penetrator band. From here, we follow the tilt of the diagonal down to the scale calling out the electrical power required—in this case approximately 50 watts of amplifier power. These penetrators may be rated at, say, 10 watts apiece, but for conservative operation and more widespread (*Continued on page* 63)

P. A. Loudspeaker Principles

(*Continued from page 26*)

distribution of units, let us operate them at 5 watts input. Hence, ten of these units, uniformly distributed, would cover the area adequately.

As a quick alternate, suppose this same volume housed just a large automobile service station and, rather than spot coverage, a single wall-mounted medium-power projector would do the job. In this instance, the vertical line would drop down to the medium-power projector band. Then following the slope of the diagonal we arrive at about 30 watts of power required, which one of these projectors can handle easily.

SECTION 3— CONSTANT-VOLTAGE SYSTEM

Contrary to popular belief, constant-voltage systems do not eliminate the need for impedance matching. The impedance matching is done *automatically* by selecting the proper *power* taps. It is as simple as changing a light bulb in a lamp. The user does not worry about impedances when making the change, but the manufacturer of the bulb did. He knows he has a 120-volt line to contend with which the power company guarantees to be "constant" within limits. Knowing this voltage is constant, the light-bulb manufacturer simply makes the impedance of a 25-watt bulb such that it will draw this amount of power from the 120-volt line, or the impedance of a 50-watt bulb so that it will draw 50 watts of power. As long as the source voltage remains constant, and as specified, the bulb will draw its rated power.

So it is with the 70.7 (or 25)-volt constant-voltage system for p.a. use. The sound installer has had the impedance problem taken care of for him by the speaker manufacturer. The transformer that he ties onto the line and then connects to the speaker is marked in *wattage* inputs. There is no need to calculate impedances. If ten sound penetrators are to be used and each one is to take 5 watts, he simply selects the 5-watt tap on the primary of the transformer and ties it directly across the p.a. amplifier's output supply line. To add another speaker, simply adjust its power tap and put it directly across the line—just as you would use a 25-watt bulb in one socket and a 50-watt bulb in the other socket of a table lamp. It becomes just as easy to adjust the sound power into any one spot with complete disregard of the adjustment of any other speaker.

Of course, in using this system: (1) The total power supplied to all the speakers in the system must not exceed the amplifier rating. (2) The power rating of the matching transformer must be adequate for the power consumed by its associated speaker load. (3) Matching transformer secondaries must be terminated by an equivalent speaker load.

Up to the point where the amplifier is not delivering its full rated power, the use of this system results in an impedance mismatch on the amplifier. However, since we are not using the maximum output power from the amplifier, the mismatch can be readily tolerated. ▲