Keep

the public address

HANDBOOK

for the

COMPOUND DIFFRACTION PROJECTOR*

Includes Complete Information on—

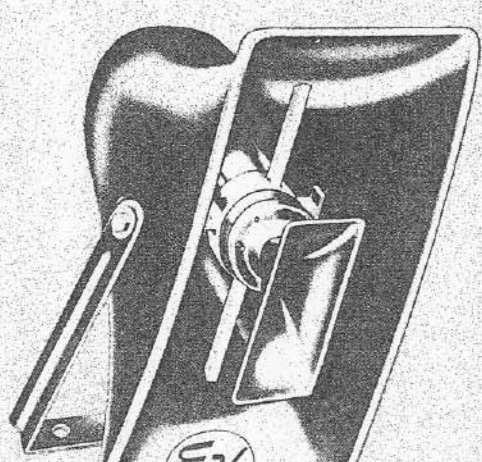
- Making Sound Surveys
- The Compound Diffraction Projector
- The Employment of Equipment
- Maintenance and Repair
- Charts, Rules, Formulas
- And All Essential Information on the Status of the Art

*Design Patent 169,904
Additional Patent Pending

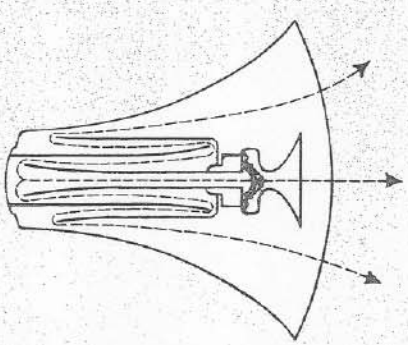
PRICE · THIRTY-FIVE CENTS

Electro-Voice

404 CARROLL STREET • BUCHANAN, MICH. Export: 13 E. 40th St., N.Y. 16, U.S.A. Cables: Arlab



E-V Model 848 Compound Diffraction Projector.



How the sides of the single diaphragm are coupled to the two coaxial horns.

Foreword

This is the story of the *Compound Diffraction Projector* Loudspeaker System. In what follows, its development, methods of employment and the theory behind its operation are disclosed. In the aggregate this manual will discuss the suitability of the *CDP* Loudspeaker to its ordained purpose: the projection of quality speech and music in all commercial sound applications.

The Diffraction Principle

A few years ago, Louis Hoodwin, a young physicist on the E-V Engineering Staff, walked into the office of the Chief Engineer and handed him an equation: the mathematics of a sound projector designed along the optical science.

This mathematical equation was first brought to tangible form in the novel Hoodwin 8-HD tweeter horn, which has been widely used in high fidelity applications, such as the Electro-Voice Regency speaker system. In the *Compound Diffraction Projector* this new mathematical formula has found its complete fulfillment in accomplishing a speaker system of much greater range and efficiency.

Basically, these projectors are diffraction horns working in the same manner as an optical slit. When this slit width is *shorter* than the wave length of the sound it passes, the sound energy is highly dispersed in the *direction of this short dimension*. This wide angle dispersion of high frequencies opened a new field of application for projector horns applied to public address and general sound work.

Coaxial Horns

In addition, there is a second major development of the highest importance in the *CDP* design. This is the feature of acoustically loading both sides of the diaphragm with respective horns for the high and low frequencies. By this means, a true coaxial projector is achieved with super-wide-range characteristics. The result is a highly engineered, efficient, rugged and economical unit of phenomenal performance.

Section 1

THE STATUS OF THE PUBLIC ADDRESS ART PRIOR TO THE COMPOUND DIFFRACTION PROJECTOR LOUDSPEAKER

In order to properly evaluate a new product, it is best to survey the prior art in the field and determine the weaknesses that should be corrected by the later development.

Before the advent of the *CDP* loudspeaker, the mere term "Public Address", or "PA", denoted a characteristic tinny sound of poor, degraded quality. This concept of low quality, engendered solely by the reflex trumpet employed almost universally, attached itself to the amplifiers and microphones also. But this stigma is really without cause, for the quality of microphone and amplifiers exceeds by many times that of the conventional PA reproducer.

THREE MAJOR POINTS TO CONSIDER IN PUBLIC ADDRESS PROJECTORS

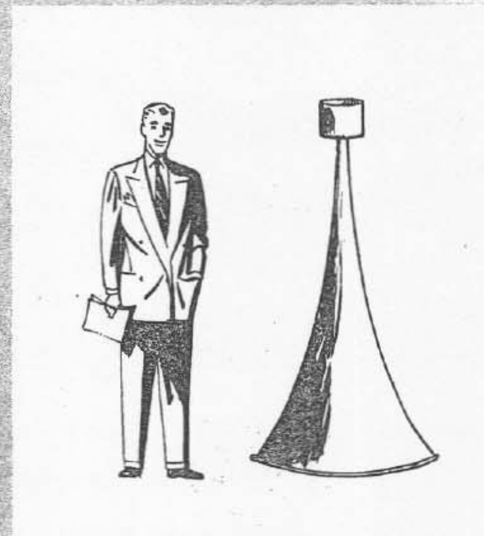
In evaluating any public address loudspeaker system, the important acoustic properties to be considered are efficiency, polar distribution, frequency response and distortion.

Efficiency

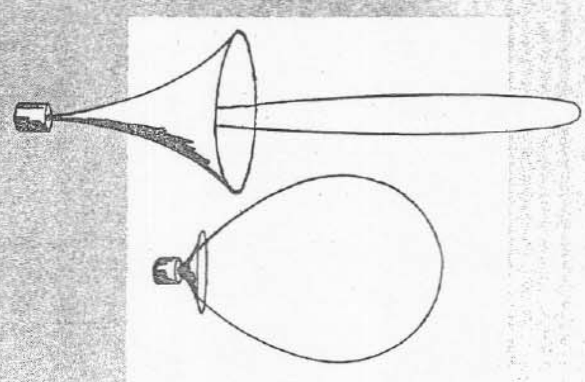
In a domestic reproducing system where the amplifier is usually capable of producing 5 to 6 watts of fairly clean signal, a loudspeaker with an efficiency of only 5% can create a sound intensity level much higher than that used in the average living room. But, in a public address system, the amplification power required is generally very large and any improvement in loudspeaker efficiency will result in smaller amplifier size and expense. Since a horn is the most efficient known means for coupling a vibrating diaphragm to the atmosphere, horn loudspeakers are usually used for public address installations.

Dispersion

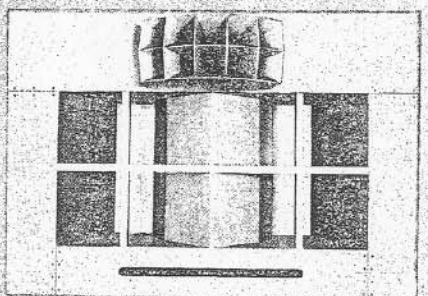
Straight Trumpet Horns. The simplest types of horns are the straight trumpets. But they are not in widespread use today because of their unwieldy size and narrow high frequency polar pattern. A typical horn with a 115 cycle cutoff has a 30″ diameter bell and is 6′ long. At low frequencies such horns distribute their sound energy widely, but as the frequency rises, they concentrate more of the energy on the axis until, at high frequencies, they produce a very narrow beam of sound. Although all horns possess these characteristics, horns with large mouths have narrower polar patterns than horns with small mouths. Since a horn with a large mouth is required for good bass response, the user must choose between using many large horns for good quality, wide angle distribution, or fewer small horns with a resultant sacrifice in quality.



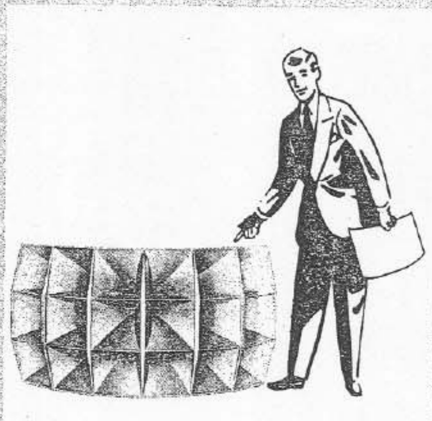
3. Straight trumpet with 115 cps cutoff showing relative size. A trumpet of this size inherently beams the high frequencies over a very narrow angle.



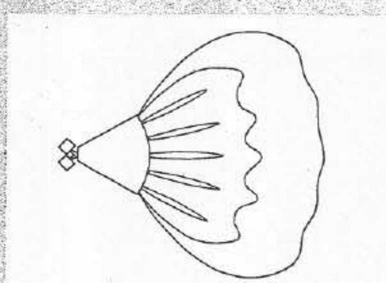
4. Size of horn has a direct bearing on spreading of high frequencies. Note the wider high frequency dispersion of the smaller horn.



4A: 40 watt theater type Loudspeaker System.



5. Typical cellular horn covering 60° x 120° angle. Horn is normally crossed over at 400 cps to protect driver units from excessive bass excursions and has a 250 cps cutoff.



5A. Pinpointing effect at higher frequencies in use of cellular horns.

6. Typical reentrant trumpet with 20" bell diameter.

Multicellular Horns. Even the small straight trumpet does not provide adequate polar distribution for most installations. In order to overcome this fault, multicellular horns are often used. These horns are actually many small straight trumpets, driven through a common throat by one or more driver units.

Where high-quality, wide-range reproduction is required, the loudspeaker system usually consists of a large bin-type "woofer" horn, and a multicellular "tweeter" horn. Such systems are found in motion picture theaters and halls where the acoustics are unusually good. The efficiency of such a system is excellent, and the polar pattern is limited only by the configuration of the array of cells. But, in the construction of multicellular horns, a constriction is formed at the throats of the cells which seriously reduces high frequency response. In addition, the individual cells show a pinpointing effect at the higher frequencies.

When a system is to be used mainly for speech, or in a reverberant hall, as is usually the case, the "woofer" is often omitted and multicellular horns are used alone. The largest of such horns usually have low frequency cutoffs of 250 cycles, (the so-called 400 cps crossover horns) and although speech intelligibility is good, the lack of bass response produces poor quality of reproduction.

Multicellular horns are very expensive to make and their large weight and bulk make them virtually unusable for portable equipment. A typical horn consisting of three banks of six cells with a 250 cycle cutoff weighs about 150 pounds and is 43" wide, 28" high, and 34" deep.

A further fault of the reentrant horn is that it has effectively the same polar response as a straight trumpet. Most of the high frequency energy that it does project is concentrated in a narrow beam on the axis. This type of polar response is useful when it is necessary to serve only a very small, highly concentrated audience. But, in most public address applications, the audience is so widely dispersed that polar distribution greater than 100° is required. With reentrant horns, as with straight trumpets, this can only be accomplished by using a multitude of horns.

◆

Response Range

Intelligibility Problems In Prior Art Trumpets and Horns. The major point in the consideration of the lack of quality in prior art industrial loudspeakers is the limited response above the 4,000 cps region. This is due to two causes: the first is that it is difficult to design a driver unit which will reproduce both low frequencies (100-1,000 cps) and high frequencies (to 10,000 cps). Proper design calls for a smaller throat for the higher tones, and a larger throat for the lower frequencies.

Secondly, when the dimensions across the mouth *at the ends of the sections* of the reentrant horns are larger than ½ wavelength, destructive interference reduces the output. This occurs mostly beyond 3,500 cps.

In the transmission of speech this means that intelligibility is lowered by a large amount in the range over 3,000 cps. French and Steinberg[1] state that a range response to 7,000 cps is required for perception of full articulation. To amplify this important fact, *The most accepted horn today lacks a full octave of reproducing the frequencies required even for speech.* For best music reproduction, this range requirement is even greater. Good music response includes flat reproduction to 10,000 cps.

Problems In Coverage With Reflex Trumpets: A 20" diameter reentrant horn concentrates most of the high frequency energy on its axis. *At 25 degrees off the axis response at 3,000 cps is 9 db down, exactly ½ loudness.* If the audience is dispersed laterally, as it usually is, a greater number of horns must be used to achieve uniform coverage with even the poor signal quality of which the reentrant horn is capable. To attempt coverage with only a few horns with high amplifier powers results in either uncomfortable loudness for those who are in front of the horns, or a sound level unsatisfactorily low for those who are off to the side.

In proper amounts bass is absolutely necessary for acceptable quality in music. On the other hand, *too much* low frequency energy causes masking of the highs, is conducive to acoustic feedback, and seriously limits the power which can be applied to the driver unit. The old reentrant horn as we know it does not have sufficient bass. This is occasioned somewhat by the compromises required to achieve even the inadequate high frequency response. The ideal bass response for various installations is treated later on in this handbook.

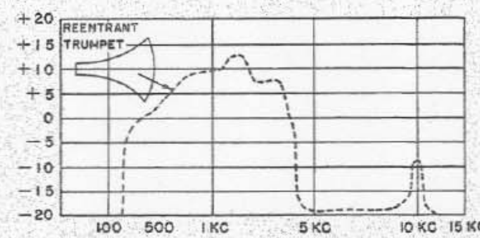
WHY REENTRANT TRUMPETS HAVE BEEN WIDELY USED

Reentrant Horns. The reentrant horn has been the most widely used public address loudspeaker. It was developed in order to obtain improved bass response in a unit that is relatively small and easy to handle. Its air column is folded back on itself one or more times so that the length of the unit is a fraction of the total length of the air column.

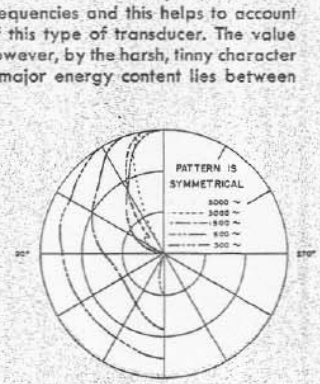
Although such horns do succeed in reproducing their bass ranges well, they are very poor in treble response. Whenever a sound wave must follow a bend whose dimensions are of the same order of magnitude as the wavelength of the sound, destructive interference reduces the amount of energy passed. In most reentrant horns this starts between 3,000 and 4,000 cycles. Such a reduction in high frequency response reduces the intelligibility of speech. For maximum intelligibility, response to at least 7,000 cycles is required.

How do we account for the past acceptance of reentrant horns? There are only a few reasons: The designs of the several manufacturers are almost identical, leaving little competition for the market with quality; present designs are rugged and dependable; they are also economical. Though straight cellular horns are superior, they have achieved practically no acceptance because of exorbitant cost and size. Refinements in reentrant design during the past ten years have been steady and are now apparently practically complete. But the poor performance from the standpoint of subjective quality has left the reentrant trumpet wholly vulnerable. The time has come for something different: a new approach with the accomplishment of far better results—*THE COMPOUND DIFFRACTION PROJECTOR.*

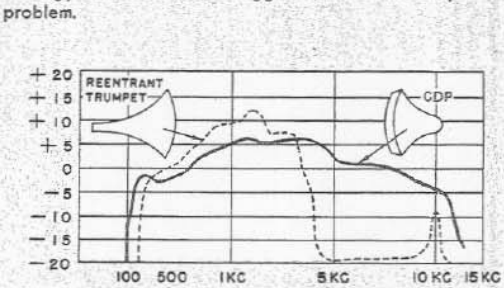
1 N. R. FRENCH & J. C. STEINBERG, *J. ACOUS. SOC. AM.* VOL. 19, PP90—119 (1947)



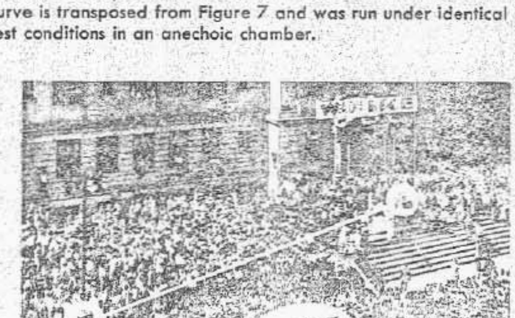
7. A frequency response curve of the most popular type of reentrant trumpet and driver unit. Observe the exceedingly high energy peak in the region 1,500 to 3,200 cps. The presence of this peak is fortunate in one respect, in that the ear is sensitive to these frequencies and this helps to account for the good efficiency of this type of transducer. The value of this peak is mitigated, however, by the harsh, tinny character of all sound in which the major energy content lies between 1,000 and 3,500 cps.



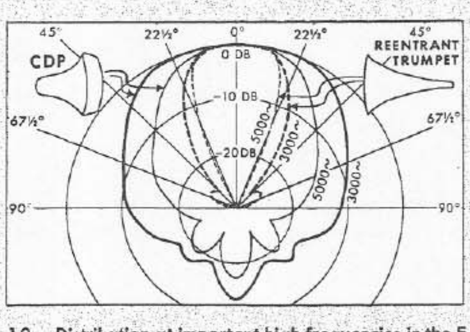
8. Polar response of the 20" reentrant trumpet. Note the very decided beaming effect at 3,000 cps. Above 3,000 cps very little energy is available, but the beaming with even this little energy indicates severe aggravation of the dispersion problem.



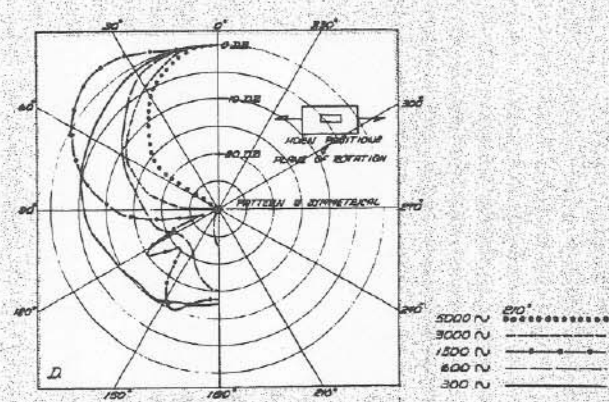
9. Frequency response curve of the E-V Model 848 Compound Diffraction Projector is shown contrasted with curve of 20" reentrant trumpet indicated with dotted line. The reentrant curve is transposed from Figure 7 and was run under identical test conditions in an anechoic chamber.



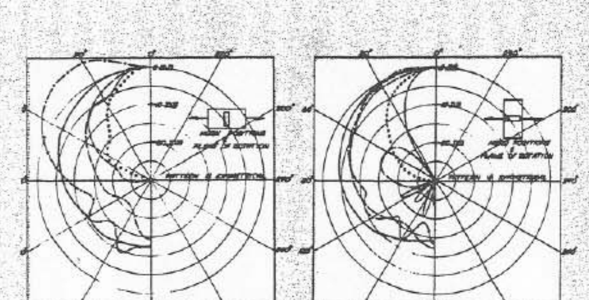
9A. Note two CDP's on post. Two other CDP's not shown were employed on this installation also, covering 27,000 people with clean, well articulated speech. Only 50 watts of audio power were used. This setup was made by Sound Engineering Company of South Bend on short notice with the very minimum of equipment.



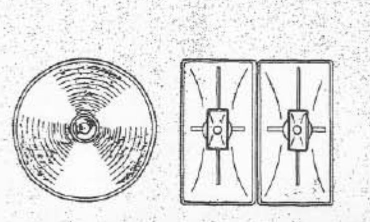
10. Distribution at important high frequencies in the E-V Compound Diffraction Projector Model 848. The dispersion of a 20" bell reentrant horn is shown with dotted lines. The diagram illustrates the *vertical* mounting of both CDP coaxial horns.



11. Dispersion with CDP in *horizontal* mounting. This position shows a more concentrated dispersion pattern for conditions requiring less high frequency spread.



12. Combination polar pattern with the CDP effected by vertical mounting of high frequency horn and horizontal mounting of low frequency horn. If feedback is experienced to the microphone at frequencies above 1,000 cps, the positions of the two horns may be reversed to assist in controlling the amount of energy projected towards the microphone position.



13. Use 2 CDP's in space normally occupied by one 20" bell reentrant.

Section 2

DESCRIPTION OF THE MODEL 848 COMPOUND DIFFRACTION PROJECTOR

What The Electro-Voice Compound Diffraction Projector Is:

The *Compound Diffraction Projector* is a coaxial loudspeaker assembly expressly designed for highest quality speech projection and musicasting. Two horns of different sizes are used: one is a large horn, especially designed for full propagation of the desired bass frequencies, and the other, a specialized small horn situated inside the mouth of the larger horn for generating high frequencies. The *throat* of each horn is properly designed to pass the full range of frequencies assigned to it in an optimum fashion.

What It Does

Through these means the *CDP* generates an audio response which is essentially flat within ±5 db, 175 to 10,000 cps on the axis.

The polar response of the *CDP* loudspeaker is unique. The elongated mouths of the diffraction assembly work in the same manner as optical diffraction slits. When the widths of the slits are short compared with the wavelengths of the sound they pass, the energy is dispersed greatly in the direction of the *short* dimensions of the slits. For this reason, the *CDP* loudspeaker spreads *120° horizontally* when it is mounted with the long dimensions of the individual horns *vertical.*

When a more concentrated polar pattern of 90° is desired, it is necessary only to mount the *Compound Diffraction Projectors* with the long dimensions of the horns horizontally.

Many cases arise where the feedback peak is above 1000 cps, the crossover point of the two horns. It is advantageous to spread the sound below 1000 cps as much as possible, and to concentrate the high beam. Figure 12 shows how the smaller high frequency horn can be turned horizontally to effect this concentration and thus miss the microphone position.

It will be seen that through appropriate adjustments, the *CDP* can accomplish four separate and distinct polar patterns, giving good control over the dispersion characteristics.

ADDITIONAL SPECIAL FEATURES

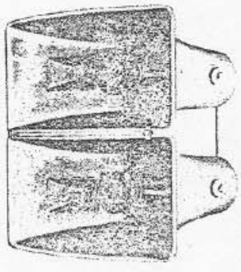
Small Size

The Model 848 *Compound Diffraction Projector* is about ½ the width of comparably rated reentrant PA horns. Two *CDP*'s can be used where only one projector was normally used before.

Where only one unit is required, the unobtrusive compactness of the *CDP* furthers the illusion required for sound reinforcement where the projectors should be kept out of sight as much as possible. This virtue of the *CDP* is assisted by the neutral gun-metal gray color.

Ideal Shape For "Stacking" In Multiple Use

The oblong shape of the *CDP* mouth presents an ideal form for circumstances where more than 25 watts of speaker power are required. By employing the Model 879 Joining Kit (See "Accessories") two or more *CDP*'s can be stacked in any array. This eliminates the need for expensive and troublesome "gondolas" for large installations, and insures a neat, workmanlike appearance in the smaller locations. Also, improved bass performance results from multiple "stacked" use.

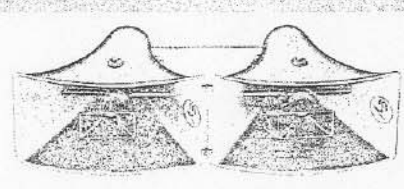


14. Stacking of CDP's accomplished through use of the Model 879 Joining Kit. Mutual loading accomplished through adjacent position and 100 cps' horn taper in basic design effects added bass response range and efficiency.

Improved Bass Response When Used In adjacent Multiple Positions

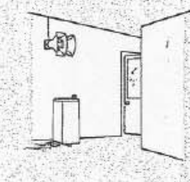
Two things promote efficient bass in a horn, the taper rate and size of the mouth. Because the shape of the *CDP* adapts itself so well to "stacking", mutual loading for the bass frequencies is attained by having the mouths of the horns adjacent. The 100 cycle taper employed in the design of the bass section promotes an unusual extension of the bass response in multiple use because adjacent horns and surfaces act as an enlargement of the mouth of the horn.

15. Horizontal placement of multiple CDP's for increased power handling and augmented bass capacity.

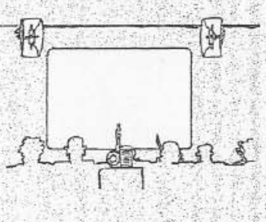


Improved Bass When Employed Singly Against Walls, In Corners, and Where Ceiling Joins Wall

Here again the 100 cycle taper in the bass section design allows the *CDP* to make full use of adjacent surfaces, especially the corners, in promoting an effective bass response associated only with much larger horns. The walls and corners act as an extension of the *CDP* Horn mouth allowing augmented propagation of bass tones.



16. *Wall Mounting*—unobtrusive—good bass response.



16A. *Where Ceiling Joins Wall* —still better bass response.

Blastproof, Splashproof, and Waterproof

The *CDP* can be used in the most extreme conditions of temperature, humidity and vibration, both indoors and out. All parts are impervious to moisture and corrosion. Steel parts are heavily plated. The *CDP* can be repeatedly submerged while operating and *will clear itself of water while playing*. No injurious effects will be observed from such use.

Because there are no sealed cavities on either side of the diaphragm in the *CDP*, it is inherently blastproof, all pressures automatically equalizing themselves.

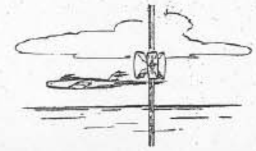
16B. *In the Ceiling Corner*—best bass response from a single CDP.

Indestructible Voice Coil and Diaphragm Assembly

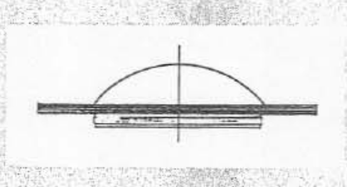
The voice coil and diaphragm assembly under ordinary use is virtually indestructible in the *CDP*. The voice coil itself is made of edgewise wound copper ribbon which provides great resistance to warping or bending. Voice coil leads are fatigue-proof, silver-plated braid and are not susceptible to cracking and failure.

Representative samples of this diaphragm assembly have been subjected to 25 watts at 60 cps continuously, and without the loading of the horns applied, *for periods of three weeks* without failure. This is equivalent to many thousands of hours of use at normal rating.

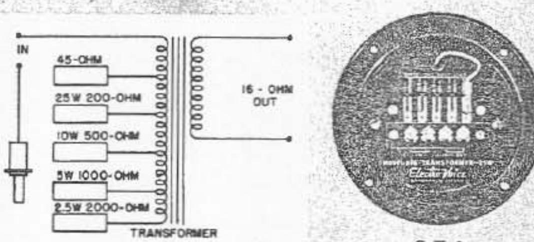
17. Splashproof and waterproof—the CDP withstands the rigors of the elements dependably and sustains 100% operation under the worst abuse.



17A. The CDP is blastproof. Both sides of diaphragm are open to the outside air, thus equalizing all pressures regardless of intensity.



18. Drawing of diaphragm assembly.



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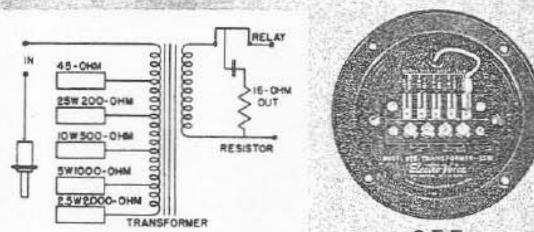
19. Model 876—25 Watt Line Matching Transformer.



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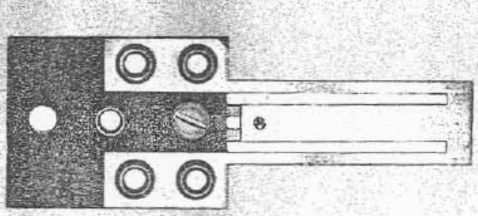
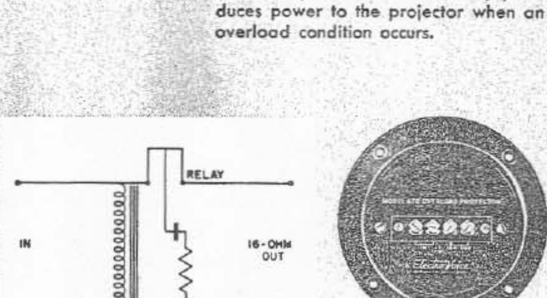
20. Model 877—25 Watt Line Matching Transformer with overload relay.



21. The Bi-metallic Overload Relay used in the Model 877 assembly. This relay is shunted by a resistor which simply reduces power to the projector when an overload condition occurs.



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22. Model 878 Bass and Thermal Overload Protector. Has same features of Model 877 but inductor is used in place of transformer for bass protection.

Diaphragm Assembly Is Field Replaceable

If the diaphragm is damaged through extreme overload or abuse, it is economically and easily replaced in the field. The diaphragm assembly for the *CDP* is replaceable simply by unscrewing the small high frequency horn and taking out four readily accessible screws. The driver cover then can be removed and the voice coil and diaphragm assembly may be exchanged. No soldering is required. Perfect alignment is automatic.

PERFORMANCE SPECIFICATIONS

RATED INPUT POWER: 25 watts

INPUT IMPEDANCE: 16 ohms

CROSSOVER FREQUENCY: 1000 cps

FLAT RESPONSE RANGE: ± 5 db from 175 to 10,000 cps

FOUR POLAR PATTERNS: 120° in vertical mounting and 90° dispersion in horizontal position. With HF horn set horizontally and LF horn set vertically, Dispersion is 90° above 1000 cps and 120° below 1000 cps. *Figures 10, 11, 12.*

PHASING: A positive voltage applied to the voice coil terminal *T-1* will cause the diaphragm to move forward, or away from the magnet and towards the front of the Projector

PHYSICAL SPECIFICATIONS

DIMENSIONS: 10½" wide at mouth by 20½" high at mouth by 20" deep overall

WEIGHT: 12 lbs. net; 15 lbs. shipping

Model 848 . . . . list price $69.50

ACCESSORIES

Model 876—25 Watt Line Matching Transformer. In protective case for mounting on rear of the 848 system. Primary taps for 25, 10, 5 and 2.5 watts with 70-volt line. Impedance taps of 45, 200, 500, 1000 and 2000 ohms. 45-ohm tap is for intercom use. Transformer by-passes frequencies below 848 Horn cutoff in order to afford protection to the diaphragm against overload conditions up to 200 percent of normal load. Case extends 3½" behind Projector when mounted. Supplied with necessary screws for mounting in holes provided on rear of *CDP* horn. 5¼" maximum diameter. *Weight:* 3 lbs. net; 4 lbs. shipping.

Model 876 . . . . list price $16.50

Model 877—25 Watt Line Matching Transformer With Overload Relay. Same as above, but with added full-range thermal bimetallic relay for maximum protection against overload in amounts up to 100%. Overload conditions will reduce power on Projector only and will not render system inoperative. Automatically resets to full sensitivity of *CDP* when overload condition clears itself. Supplied with necessary screws for mounting in holes provided on rear of *CDP* horn. *Size:* same dimensions as 876 Transformer. *Weight:* 3 lbs. net; 4 lbs. shipping.

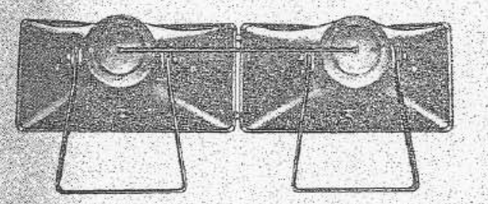
Model 877 . . . . list price $17.50

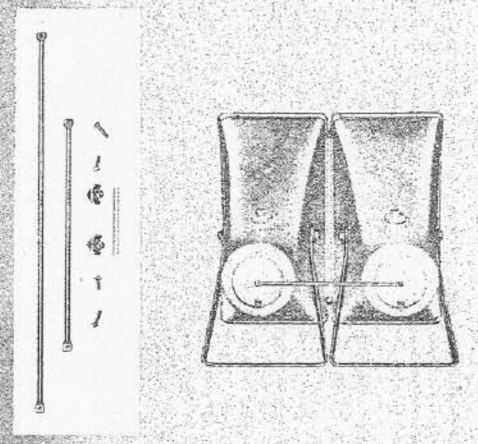
Model 878 Bass and Thermal Overload Protector. Prevents excessive diaphragm excursion due to frequencies below 848 Horn cutoff. Automatically reduces power to driver when 25-watt limit is exceeded. Mounted in case duplicate of Model 876 Transformer, and allows usual 16 ohm input. *Weight:* 3 lbs. net; 4 lbs. shipping.

Model 878 . . . . list price $16.50

Model 879 Joining Kit. Required for fastening multiple projectors together in any array; use one Model 879 Kit for each junction between 2 horns. *Weight:* 8 oz. net; 1 lb. shipping.

Model 879 . . . . list price $2.75





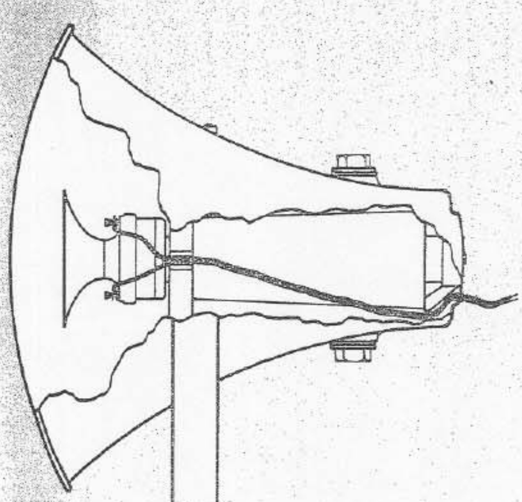
23. Model 879 Joining Kit. Illustration shows method of coupling two or more horns together.

PREPARATION FOR USE

The *CDP* is shipped assembled and ready for use.

The transmission line may be connected directly to terminals *T-1* and *T-2* on the driver unit. But, for a neater and stronger connection, it is recommended that the line be fed through the grommet at the rear of the large bell and the hole in the cross bracket. To install the line in this manner, follow these steps:

1. Bend the end of the cable so that it is shaped into a semi-circle about 1″ in diameter.
2. Insert the cable end through the grommet so that the end will pass outside the large phenolic tube.
3. Reach into the front of the horn, grasp the cable and pull it forward.
4. Tie a knot in the cable to act as a strain relief against the grommet.
5. Feed the cable through the hole in the cross bracket and fasten two leads to terminals *T-1* and *T-2*.



24. Crossectional view of CDP showing method of connecting feed cable.

WARRANTY

ELECTRO-VOICE, INC. warrants each new product manufactured by it to be free from defective material or factory workmanship and agrees to repair or exchange any part thereof which under normal installation, use and service, discloses such defect. Our obligation under this warranty is limited to repairing or exchanging any defective part, with the exception of tubes, if that part is returned, transportation prepaid, within ninety (90) days from the date of original purchase by the consumer through our authorized dealer from whom the consumer purchased this product. This warranty does not apply to any of our products which have been repaired or altered in any way so as, in our judgement, to injure their stability or reliability or which have been subject to misuse, negligence, or accident, or which have had the serial number altered, effaced, or removed. Neither does this warranty apply to any of our products which have been connected, installed, or adjusted otherwise than in accordance with the instructions furnished by us. Accessories not of our manufacture used with this product are not covered by this warranty.

This warranty is in lieu of all other warranties expressed or implied and no representative or person is authorized to assume for us any other liability in connection with the sales of our product.

Section 3

EMPLOYMENT OF MODEL 848 COMPOUND DIFFRACTION PROJECTOR

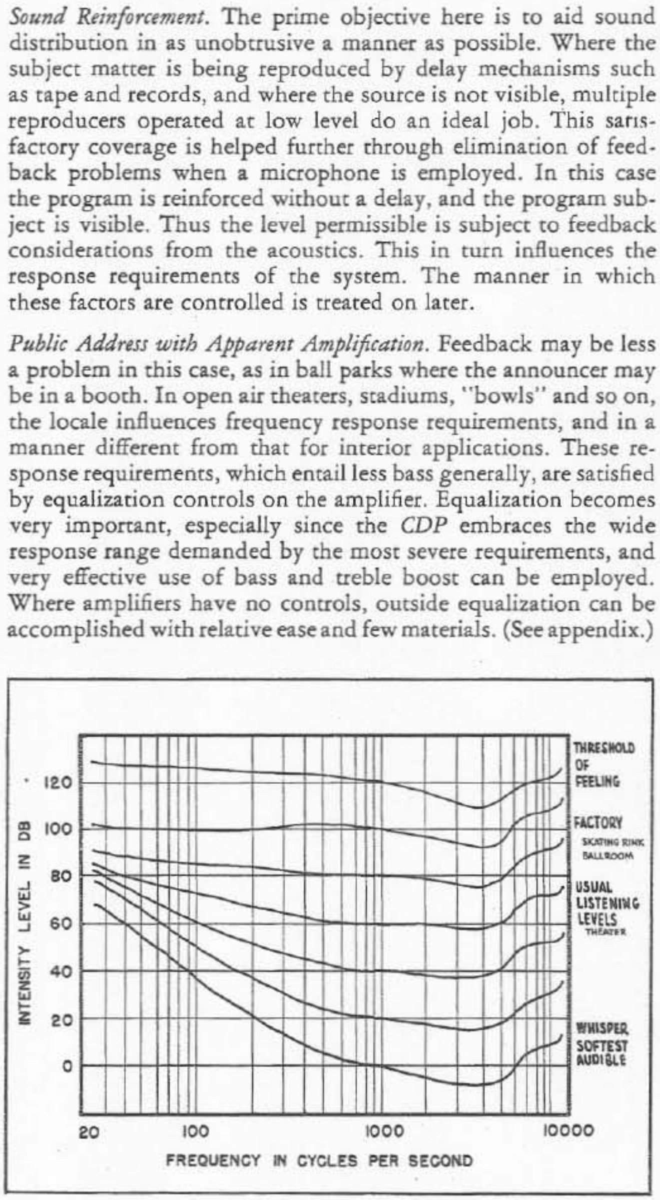
BROAD OPERATIONAL CONSIDERATIONS OF IMPORTANCE IN PUBLIC ADDRESS SPEAKER SYSTEMS

General Considerations

The employment of loudspeakers for public address is approached from two view points: *sound reinforcement*, where the audience is unconscious of the sound system employed, and *public address*, where the use of amplification is very apparent.

Sound Reinforcement. The prime objective here is to aid sound distribution in as unobtrusive a manner as possible. Where the subject matter is being reproduced by delay mechanisms such as tape and records, and where the source is not visible, multiple reproducers operated at low level do an ideal job. This satisfactory coverage is helped further through elimination of feedback problems when a microphone is employed. In this case the program is reinforced without a delay, and the program subject is visible. Thus the level permissible is subject to feedback considerations from the acoustics. This in turn influences the response requirements of the system. The manner in which these factors are controlled is treated on later.

Public Address with Apparent Amplification. Feedback may be less a problem in this case, as in ball parks where the announcer may be in a booth. In open air theaters, stadiums, "bowls" and so on, the locale influences frequency response requirements, and in a manner different from that for interior applications. These response requirements, which entail less bass generally, are satisfied by equalization controls on the amplifier. Equalization becomes very important, especially since the *CDP* embraces the wide response range demanded by the most severe requirements, and very effective use of bass and treble boost can be employed. Where amplifiers have no controls, outside equalization can be accomplished with relative ease and few materials. (See appendix.)



25. The well-known Fletcher-Munson curves disclosing ear sensitivity to the bass and treble frequencies at various sound levels.

Detail Requirements

The differences in the two viewpoints expressed in the preceding paragraphs require a compatibility in present day PA horns *which is unusually well assisted by employment of the CDP.*

Response Range Requirements. Large enclosed auditoriums, coliseums, school theaters, and the like almost invariably lack acoustical treatment. In consequence an enclosure of the dimensions 125′ W x 70′ H x 250′ L, to cite a typical case, would be likely to have a natural period of about 150 cps, augmenting all sound in this region by as much as 15 to 20 db. Feedback will always seize on this peak, in many cases rendering the system completely unusable because of garbling, or masking by this bass, and further, because of the high possibility of feedback in the low frequency region.

There are usually 3 to 4 lesser peaks above and below this frequency. This reinforcement does not exist in the open air. The obvious conclusion is that it is necessary to supply two types of response from the amplifier, all others points being equal: one response with *extended* bass for music out-of-doors, and another response for speech and music indoors with *attenuated* bass, which should be rolled off rapidly at about 300 cps.

Treble or Mid-Range Frequencies. From previous studies the importance of good efficiency in the 5 kc range cannot be underestimated, particularly when sound levels are 80 db and lower. This low level is almost uniformly the rule from the usual listening positions. Reference to the Fletcher-Munson curves (*Fig. 25*) discloses highly peaked ear sensitivity below the level mentioned, which in turn permits high apparent efficiencies with economy of speaker cost. Intelligibility and "Presence", are also vastly augmented by good efficiency in this range. It has been reasonably well established that ample response in the treble range around 5 kc is the design objective for the acoustic levels involved at the average listening position. This is difficult to obtain in present day amplifiers without affecting the frequencies beyond this point. The sensitivity of the *CDP* in this range is excellent.

High Frequency Response. From the commercial aspect response beyond 5 kc is of importance. At normal listening positions, say 100′ from the source, we find attenuation of higher frequencies through the air to be about 3 db. At greater distances the attenuation becomes very violent. The appendix shows a chart graphically illustrating this. Objectively, reasonable higher frequency response should be the goal because of added quality and articulation derived from the fricative consonants. In very reverberent auditoriums, as most coliseums and auditoriums are, it is sometimes necessary to attenuate frequencies below 300 cps. while accentuating the higher frequencies especially in the range of 3 to 5 kc.

Recapitulation of Frequency Response Requirements. It is advantageous to have the following types of PA response characteristics for the two main classifications of use below:

Inside Use. A rolloff of the frequencies below 300 cps, a rise of 3 to 5 db at 5 kc, and as extended higher frequency response as possible consistent with power and safety are desirable.

It is to be noted that a higher low-frequency cutoff promotes extension of the high range because greater acoustic loading is possible by means of closely situated loading plugs at the diaphragm. The *CDP* HF chamber and horn ideally promotes this effect, with bass being preserved at nearly the optimum powers required, even with the bass tone control somewhat attenuated at the amplifier.

Outside Use. LF response should extend to the region 150 cps or lower to make up for lack of bass reinforcement in open air. Pleasing quality appears to depend on reasonable bottom response on speech, and this is particularly true of music. In this last case, the amplifier bass boost can be regulated for most pleasing quality with some sacrifice in over-all power handling ability of the *CDP*.

Directional Control

Inside Use. It is especially important that the most accurate directional control possible be provided for PA units when used in interiors. A coliseum of the dimensions previously mentioned, 125′ W x 70′ H x 250′ L, has an average reverberation time of 8.5 seconds. This drastically limits the amount of power which can be employed because of garbling, unless the sound can be directed away from the reflecting ceiling, walls and exposed floor areas, and projected as completely as possible to the usable and most absorbent locations only, i.e., the audience. It should be noted that by far the most successful projector units in this regard have previously been of the exponential cellular type. Each cell intercepts reasonably a solid angle of 20°. Thus, cell configuration has permitted practical control. With the *CDP* four different polar patterns are available from the single horn as shown in *Fig. 25A*. These cover almost every conceivable requirement.

Outside Use. The feature of controlling distribution angles is almost equally important on exteriors. Open air stadiums are vitally concerned with the random distribution of sound in the disturbing of neighboring residents. Sound must be confined to the actual audience area. Ball parks are noted for lack of intelligibility due to reflections from far signboards and half-filled bleachers. The *CDP*, with its well defined coverage angles, allows the desired control of signal spread and simplifies PA problems.

Power Requirements

Determination of the number of *CDP* units required for a given location is not difficult. The most simple method is to borrow from the experience of motion picture engineers for setting the minimums on the basis of seats or people to be covered.

The table below will establish a base. These figures should be memorized:

AMPLIFIER AND CDP REQUIREMENTS

MOTION PICTURE THEATER CONDITIONS

PERSONS AND/OR SEATS	AMPLIFIER	NO. OF UNITS
750	20 Watts	1 CDP
1500	30 Watts	2 CDP's
3000	60 Watts	3 CDP's
6000	80 Watts	4 CDP's

FOR AUDITORIUMS, COLISEUMS, ARENAS AND OPEN AIR CONDITIONS DOUBLE THE AMPLIFIER POWER AND NUMBER OF CDP UNITS. FOR ROLLER SKATING RINKS, FACTORIES AND CONDITIONS OF HIGH AMBIENT NOISE, MULTIPLY BASIC REQUIREMENTS OF QUIET MOTION PICTURE HOUSE BY THREE TIMES THE AMPLIFIER POWER AND NUMBER OF CDP UNITS.

Involved calculations on the basis of absorption and reverberation time are of little consequence. It is exceedingly rare that the sound contractor can do anything about these. The high intelligibility and projection qualities of the *CDP* minimize all the problems, and eventuate in thoroughly commercial solutions to the past complexities experienced in prescribing for a difficult PA situation.

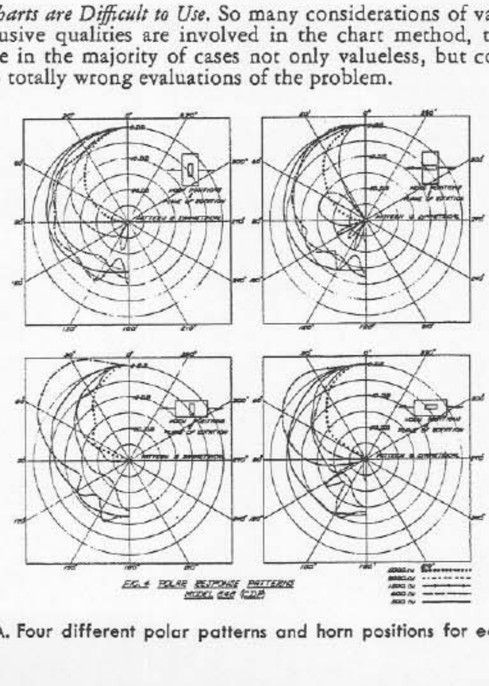
Caution Note: Many charts have been published in an attempt to provide a mathematical means of accurately determining the number and power of speakers required for an area of a certain cubage. These charts also ascribe fairly definite noise levels to types of backgrounds, such as churches, factories, waiting rooms, and so on.

A few words of caution are in order because the efficacy of such charts is open to considerable question for these reasons:

a. *Error in Computation of Requirement When Figured by Cubage:* Cubage always takes into account, erroneously, the height of the listening area, *without* considering that coverage *above* a certain height is neither required nor desirable. For instance, the highest point to which sound should be directed is 5 feet above the floor of the most distant position in the house where an individual can be placed. Thus height, per se, in such computations will evoke a wrong answer for the amplifier power and number of projectors to be employed.

b. *Consideration of Noise Levels Strictly in Terms of Decibels Affords a Difficult Base for Calculation.* These calculations do not take into account the response range and articulation index of the loudspeakers to be employed. These vitally effect the power requirements by as much as *four and five hundred percent*. Moreover the noise levels ascribed to a factory, for example, are of small significance: differences of 20 db are certainly not unusual. The charts indicating average requirements of 80 watts can be off by as much as *70 watts* on the basis employed!

c. *Charts are Difficult to Use.* So many considerations of vague and elusive qualities are involved in the chart method, that they are in the majority of cases not only valueless, but conducive to totally wrong evaluations of the problem.



25A. Four different polar patterns and horn positions for each.

MAKING SOUND SURVEYS AND SELLING THE JOB

In dealing with contractors, architects, and other principals concerned with a large PA job, reports are essential. A well worded and organized report ofttimes is the major factor in accomplishing the contract for the sound equipment sales engineer. These examples of surveys and reports below eventuated in successful sales, and can form a pattern.

For very noisy locations where the size of the job warrants, a noise meter is helpful. General Radio makes two types, and the H. H. Scott Company has a very compact and practical unit.

Actual Sound Survey and Report on a Large Factory With the Most Severe Conditions to be Encountered

REPORT OF MEETING AT: (Place of Survey)

MEETING CALLED BY: (Party Soliciting Bid)

PURPOSE OF MEETING: To survey the requirements for modernizing and expanding a paging and announcing system for the

______________________________ corporation.

THOSE ATTENDING: ____________ ____________

____________ ____________

DESCRIPTION OF LOCATIONS FOR SOUND REINFORCEMENT:

The areas to be covered by a paging and announce system are two sections of a large area used for the fabrication and storage of large unit air conditioning equipment and parts. The area is approximately 50 feet high, divided by a narrow internal office housing traversing the length of the structure. Floor plan and recommended speaker positioning is shown on Exhibit "A".

TESTS CONDUCTED:

1. *Noise Measurements:* Exhibit "B" illustrates the approximate distribution of noise throughout the area. Shown also on the chart is the frequency distribution in the noise itself. These measurements were conducted with a General Radio Noise-Meter.

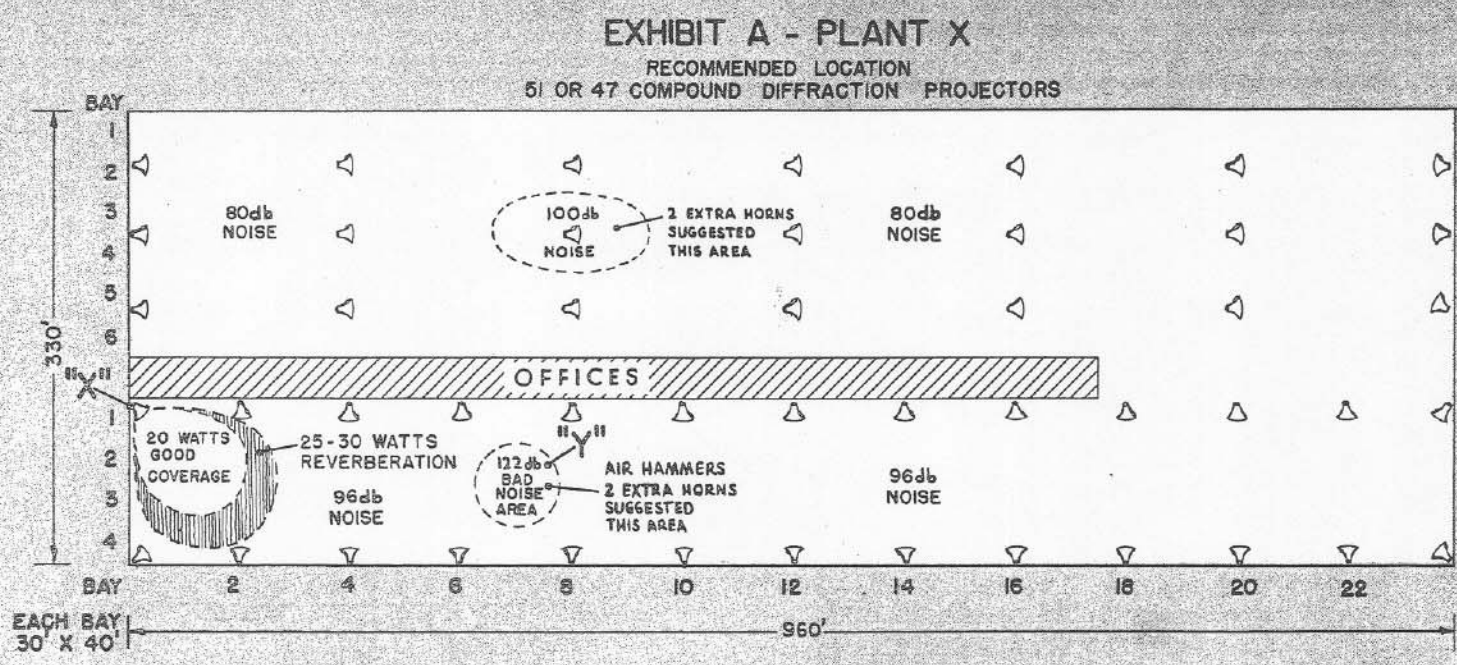
2. *Paging Test:* An Electro-Voice *Compound Diffraction Projector* Model 848 was employed with a 25 watt amplifier and an Electro-Voice Model 654 microphone. This *CDP* unit was placed at point "X" in Exhibit "A", on the balcony end intercepting an angle of 120 degrees (vertical mounting). Announcements were made using numbers, proper names, and instructions.

RESULTS OF TESTS:

1. *Storage area* on the south side of the office partitions presents no noise problem, and is simply a matter of projected distribution by an adequate number of *CDP's*, each operating at relatively low power.

2. *Fabricating area* presents a problem in the region of point "Y". 122 db of sound pressure (almost twice the power which is required to cause pain sensations) is evidenced for short periods (1 minute out of every 10). This is due to the employment of air hammers on large piece parts. 60 feet away from the hammer this pressure drops to 96 db, a practical amount which can be overcome with reasonable power and at a practical cost.

3. *Paging Test in Fabricating Area:* Refer to Exhibit "B". At 25 watts of power room reverberation begins to cause a condition of unintelligibility. This is a limit on any system which may be employed of equal quality in range response and efficiency. However, this limit includes a very practical range for a single *CDP*, resulting in a considerable saving over off-hand estimates for the large 400 cps cellular horns prior to testing.



26. Exhibit "A".

RECOMMENDATION

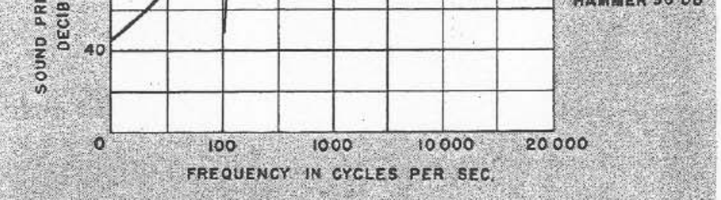
51 *CDP*'s effect 95% coverage spotted approximately as shown in Exhibit "A". When air hammers are in operation, this will allow complete intelligibility *except* in the area immediately adjacent to the bad noise area marked "Y".

REMARKS:

1. *The high intelligibility* of the recommended *CDP* speaker systems, their acceptance in engineering circles as the practical manner in which truly commercial sound coverage in noisy locations can be achieved, makes them the recommended choice for satisfactory results.
2. *Efficiency of better than 50%* means that almost 40% saving in amplifiers can be effected, 25 watts per horn being all that is required and usable.
3. *Adequate coverage* of 95% more than takes care of key personnel. To achieve 100% coverage to include area "Y" would call for impractical power requirements to overcome the intense noise of the air hammers, and the ear plugs used by the operators. It would appear that key and administrative personnel would be in the aisles and other areas easily covered by the sound system. Moreover, the powers required to cover the location at "Y" would make the other areas uncomfortable, eventuating in slowup of production.

It is not recommended that consideration be given to reentrant trumpets and Modulated Air Stream Horn Systems because of the very restricted frequency response range. Note that the spectral distribution of the noise in Exhibit "B" is quite wide, calling for a speaker system equally wide or wider in range to cut through the interference. Electro-Voice Model 848 *Compound Diffraction Projectors* will accomplish completely the results desired.

Engineer for____________________Company



27. Exhibit "B".

Typical Survey of An Indoor Arena Installation Requiring Modernization

(ICE SKATING, ROLLER SKATING, CIVIC SHOWS, DANCES POLITICAL MEETINGS, ETC.)

REPORT OF SURVEY

REPORT TO: (Name of party soliciting bid)

PLACE OF SURVEY: (________________)

PURPOSE: To survey the existing sound coverage of the______ __________ Stadium with a view to improving the quality.

METHOD OF SURVEY: The existing sound system was energized and tape and phonograph records, as well as live voice, were used as signal sources. Listening tests were made by continuously walking through all locations within the auditorium. At the conclusion of these tests, loud signals were keyed on and off after a suitable build-up period in order to determine reverberation time characteristics.

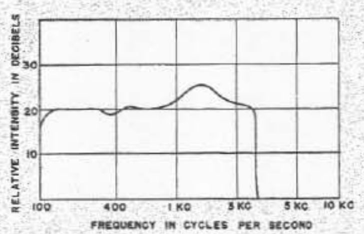
Later the control and auxiliary equipment was visibly inspected.

RESULTS OF SURVEY: *Electrical:* The control equipment is of the (________) make and was satisfactory for this class of installation. Tape at 7.5 ips. was employed for ice skating organ music. This speed is satisfactory for the quality desired. Electro-Voice 726 Cardioid microphones are used for voice and, though moisture and humidity conditions were severe, they seemed to be holding up with no difficulty being experienced.

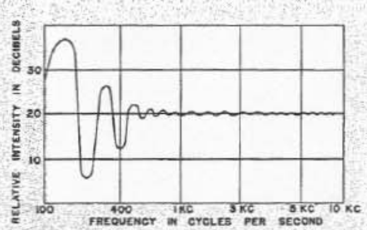
Accoustical: The response characteristic of existing reentrant horns is shown in *Fig. 28*. A general curve of the response of the auditorium 100′ from the speakers is shown approximately in *Fig. 29*. Of extreme importance is the build up of lower frequencies in steps of random spacing, a characteristic common to all large halls.

Now note *Fig. 30:* This indicates the results of combined system response and hall characteristic, and shows what is actually being heard with outmoded speaker equipment in the stadium at best listening positions.

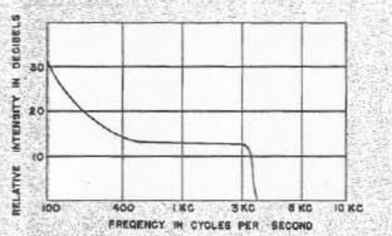
Coverage: Figure 31 shows the *distribution* of energy at several important frequencies. This is the polar pattern with respect to the higher frequencies. This pattern is common to the type of horn type projector which is now employed. For coverage under the conditions at hand their use has been superceded by the *Compound Diffraction Projector*. *CDP's* divert the concentrated narrow high frequency beam and spread it with uniformity throughout the entire listening area. Rather accurate control of these beams is also effected by the structures, permitting the energy to be concentrated at the audience only. This prevents garbling due to reflections from the ceilings and floor, and directs the sound to the most absorptive region, the audience. Thus, a higher level of sound may be employed. Moreover, this higher level obtains a greater intelligibility factor because of direct transmission to the ears of the listener without delayed reflections.



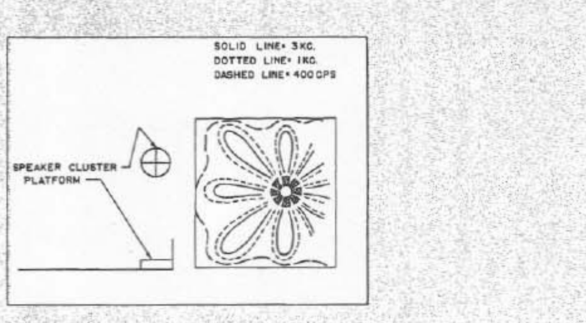
28. Speaker System Response.



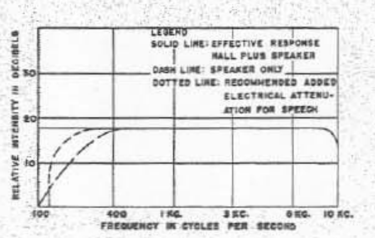
29. Hall Response Characteristic.



30. Actual Response of System and hall as now used.



31. Distribution of sound energy at important frequencies with existing system showing inadequate coverage at the higher frequencies.



32. Recommended response characteristic with Compound Diffraction Projectors.

Quality: Figure 32 shows the sound character it is possible to achieve by employing *Compound Diffraction Projectors*. The response of the electrical system is attenuated at the standard rate of 12 db per octave as shown by the dashed line. The effective result in combination with the bass reinforcement offered by the hall itself is shown by the heavy line. The dotted line shows added rolloff of bass desired for speech for maximum realism. After 3 kc a rise is noted. This is desired because of an empirical determination that the rise offsets the monaural effect of the single channel pickup system which does not parallel reality, i.e., dual transmission as with 2 ears to the separate sections of the brain. In addition, these frequencies above 3 kc are the ones required to reproduce the fricative consonants, such as *f*, *th*, *c* and *k*. Some of the labial sounds of *m*, *n*, and *b* are also present in this region. Accordingly, intelligibility requires full generation and area coverage of these tones. The present speaker system fails woefully in this regard, inasmuch as the upper useful limit of reproduction is about 3500 cycles per second, and the selective beaming at this frequency is covering only 8 sections of the hall less than 15 degrees wide. This situation is aggravated further by the masking effect of bass, as indicated in *Fig. 30*. The effects of masking of one tone by another are well known, and the present situation demonstrates the worst possible case.

CONCLUSIONS:

1. The present speaker installation of the (________________) Stadium is unsatisfactory in view of the more recent developments in the art.
2. Satisfactory operation for the stadium may be achieved by replacing the existing speaker system with a modern commercial assembly as noted under "Recommendations" below.
3. No changes to the electrical system are required.

RECOMMENDATIONS

1. It is recommended that a loudspeaker assembly consisting of eight Electro-Voice Model 848 *Compound Diffraction Projectors* be employed for speech. These should be located at "X" on the diagram. *Fig. 31.*
2. It is further recommended that the standard low frequency reproducers as used by live electronic organs be employed for organ music and switched in only for this character of music. Two each Electro-Voice 18" Super low-frequency drivers on flat baffles approximately 6x8 feet square can be used for this purpose, mounted in any convenient location.
3. A suitable switch should be used for organ music to cut in the low frequency drivers.

REMARKS:

Acoustic conditions in the (________________) Stadium are not as poor as those generally encountered in halls of this size.

This may be accounted for by the presence of a wooden ceiling with large braces of wide cross-sectional area. The absorptive coefficient of the wood is higher than metal and the large braces tend to break up low frequency standing waves.

____

Engineer for________________Company

GENERAL DISCUSSION OF PUBLIC ADDRESS REQUIREMENTS

Characteristics of Auditoriums, Stadiums and Large Interior Rooms

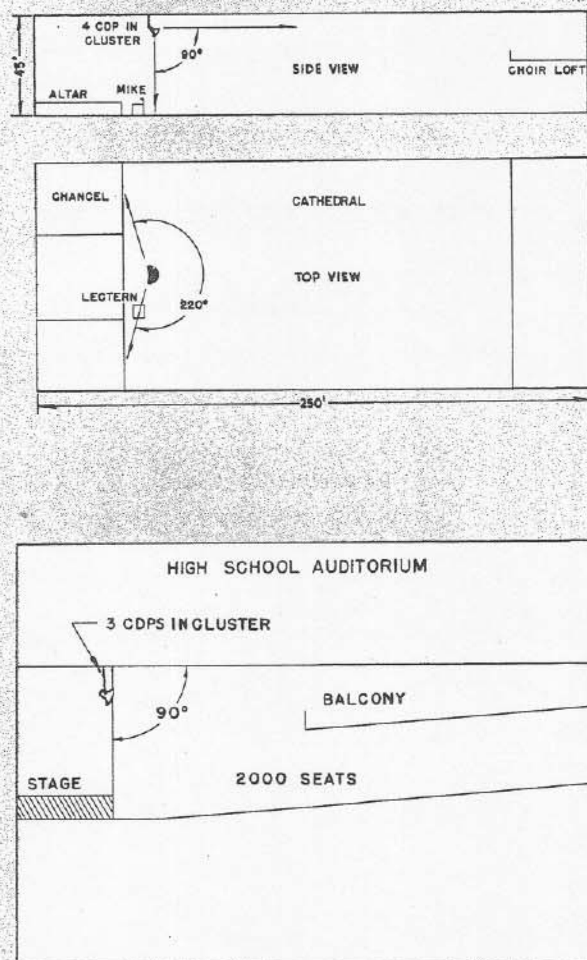
Reinforcement. The main purpose of amplification in locations covered in the heading is generally to *reinforce* the original sound. The speaker system should be as unobtrusive as possible. In this latter regard, the public address system should not be noticeable *unless* it is turned off. In the accomplishment of sound reinforcement, lower levels are generally employed than would normally be assumed for straight public address work.

Room Resonance. Room resonances are important in the consideration of a public address installation. These resonances vitally affect the amount of power which can be employed for a given location, and in addition, determine the amount of bass attenuation which is required in the amplifier itself. Large halls generally have bass reinforcement points in the region between 100 and 300 cycles according to their size; the larger rooms have lower frequency reinforcements, whereas the smaller rooms have reinforcements at higher frequencies.

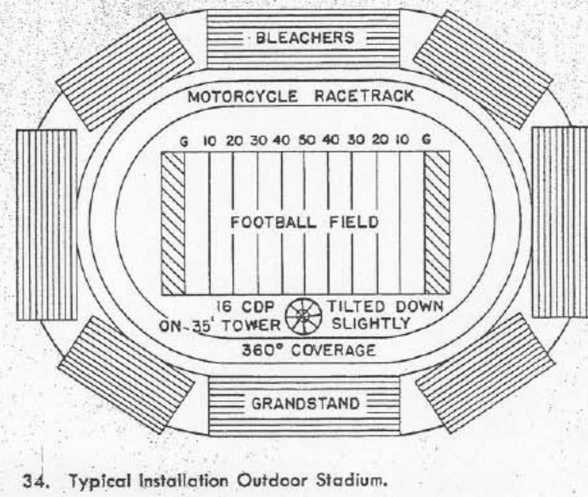
Reverberation Time. The acoustics of the hall itself and the location of large flat surfaces on the interior of the hall determine the amount of echo, or reverberation. This reverberation is the enemy of high power in the public address system because it is generally present in fairly large amounts, tends to garble speech and to make music displeasing.

The reverberation of an auditorium can be determined in several ways; the easiest method for evaluating objectionable reverberation is to employ an audio oscillator on a loudspeaker situated where the speaker or cluster of speakers is to be hung. A signal of approximately 400 cycles at a good level should be fed into the speaker and turned off abruptly. Counting in seconds the time required for the signal to fade in the auditorium, to a level which is inaudible will determine, for practical purposes, the reverberation time.

Checking Reverberation and Corrections for Excessive Liveness. There are certain optimum times for both music and speech; the optimum for music is considered generally to be about two seconds. This means that it is not advisable to have the room too dead. This is a consideration which ordinarily we do not have to worry about in large auditoriums, as they are generally too live. The optimum reverberation time for speech is only between ½ to one second at 400 cycles. In most large auditoriums it will be found that when the test speaker is spotted at random, ie., without any regard for the proper placement, the reverberation time will be as high as six to ten seconds in houses of between 6,000 to 12,000 seat capacity. Reverberation time of this long period, without corrective action, results in almost complete garbling of the speech and music. This renders the public address system almost unuseable.



33 & 33A. Representative Interior Installations.

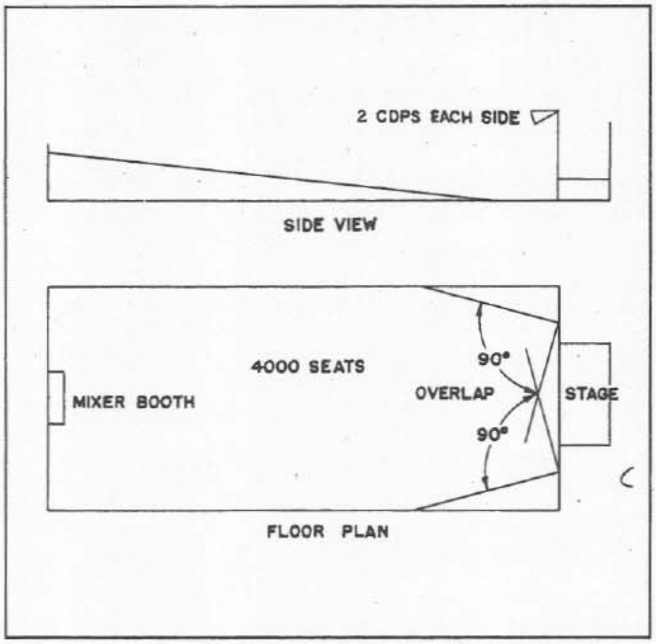


34. Typical Installation Outdoor Stadium.

The proper correction for long reverberation time is to direct the beams of the *Compound Diffraction Projectors* directly to the absorptive area. This absorptive area is formed by the audience, and the eventual test of the effectiveness of the public address system can be accomplished only with a normal attendance in the house. Good absorption will enable a higher level of power to be employed. It will also minimize the effects of feedback due to random, or reflected, sound impinging on the microphone position.

Keep Microphone Out of the Speaker Beam. It should be held in mind that the direct sound from the individual into the microphone must always be louder than the reflected sound from the public address system, or feedback will occur.

One-hundred and fifty feet in front of the loudspeaker system, about 95% of the sound heard is indirect, even in the best installations. We are concerned with the first reflection, or first bounce of the sound. The second, third, and fourth bounces are very unintelligible due to time delay, frequency discrimination by phasing out of the various sounds and natural attenuation of the sound by the reflective surfaces as they are related to the various frequencies. The loud-speaker system, or cluster of the *Compound Diffraction Projectors*, should be over the microphone, pointing away from the microphone towards the audience if at all possible. This serves several functions; it makes the sound apparently originate from the individual who is speaking because the horns are in his general location; it subdues the effects of feedback; it does much to prevent violation of the normal visual-aural continuity of the audience.



35. Open Air Theater Treatment.

Open Air Stadiums, Ball Parks and Bowls

For locations under this heading, *public address* is the goal rather than simple sound reinforcement. The single point source of the sound is very important; this means that the *Compound Diffraction Projectors* all should be as close together as possible and should spray the far points evenly from the location where the actual sound and action is taking place. This eliminates the deleterious effects caused by various time delays.

Generally speaking, speech frequencies are the most important under these conditions. It is here that the *Compound Diffraction Projector* does such a capable job because of the extended high frequency range. Fewer horns will be required than have been prescribed in the past. The diagrams, which accompany this text, will show the recommended placement under representative conditions of operation.

Under open air conditions, we are especially fortunate in some respects in that reverberation seldom constitutes a problem. Musically speaking, we never have quite enough. It is in the open air that we find the need for augmented bass response to keep the music from sounding "pinched". The reverberation time is virtually zero, whereas, for music, the optimum should be around two seconds. To overcome this, all the bass possible will assist in the illusion of increased reverberation. At times it is desirable to augment the bass response through the employment of low frequency cone speakers judiciously placed.

Minimizing Acoustic Feedback

Here are some general rules to keep in mind when placing horns under conditions of high reverberation and feedback:

1. Aim the top of the *CDP* projectors to the opposite wall no higher than 5 feet above the floor of this far wall.
2. Put the microphone in back of the projectors if at all possible. If this cannot be done, the projectors should be placed as high as possible over the microphone area.
3. In fight arenas, the microphone should be as nearly as possible directly under the *CDP* cluster, and the cluster should be kept as high as possible.
4. Lapel and breast microphones, such as the Model 646 and Model 647 Electro-Voice Lavalier units, are highly effective in reducing feedback because the announcer is ideally placed with respect to the microphone. The close direct signal from the announcer's voice will override the reflected signals from the public address system. As much as 6 db more level is possible before feedback occurs.
5. Feedback seizes on peaks in the system. The smooth response of an E-V microphone and the *Compound Diffraction Projector* make a combination which minimizes this problem.

Section 4

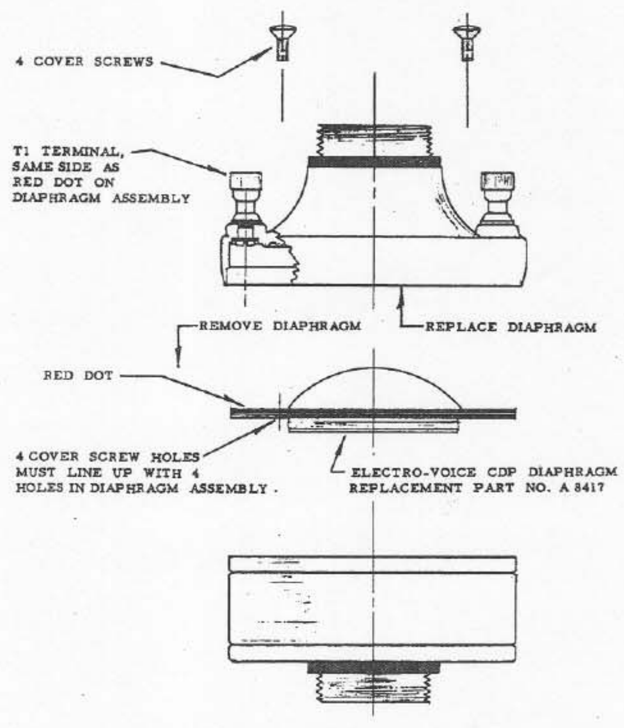
MAINTENANCE AND REPAIR

Should the *Compound Diffraction Projector* ever be excessively overloaded, the voice coil and diaphragm assembly can be replaced in the field by following the procedure outlined below: (The illustration accompanying this paragraph (*Fig. 36*) should be referenced for the points given.)

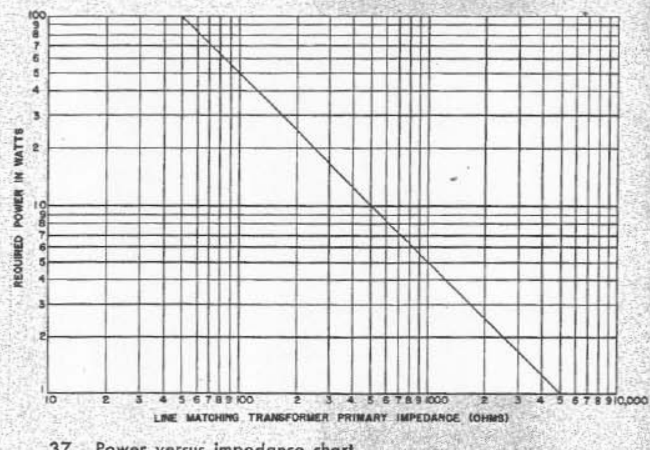
1. Unscrew the driver unit and tweeter horn from the assembly by turning to the left.
2. Remove the four screws holding the cover of the driver unit.
3. Due to the very tight fit of the cover it may be necessary to force it off the pot structure. This may be most easily accomplished by striking a few sharp blows against the back surfaces of the tweeter horn. The back of the horn may be struck against the edge of a work bench.
4. Pull the cover off as soon as it has been sufficiently loosened. This will expose the diaphragm assembly inside the cover.
5. Insert a screwdriver along the edge of the diaphragm in one of the cutouts and pry out.
6. Insert the new diaphragm assembly with the red dot over the terminal *T1* in order that the replacement diaphragm will be properly phased.
7. Reverse the procedure in disassembly, making sure that opposite screws are tightened down first and then all screws cinched up completely in rotation. Upon reassembly the *Compound Diffraction Projector* is again ready for use.

Tool required for this operation is a Philips type screwdriver.

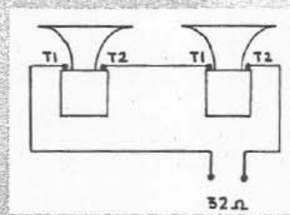
The *Compound Diffraction Projector* is fully guaranteed against all defects of manufacture and workmanship. Periodic maintenance should consist only of wiping the projector off with a cloth and removing debris and dust from this interior bell.



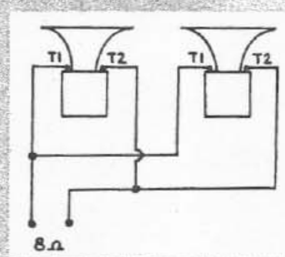
36. Exploded view of Model 828 Driver Unit used in Model 848 CDP, showing sequence of disassembly for replacing diaphragm.



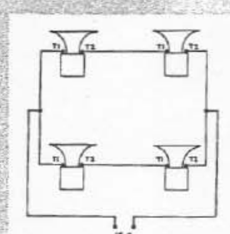
37. Power versus impedance chart.



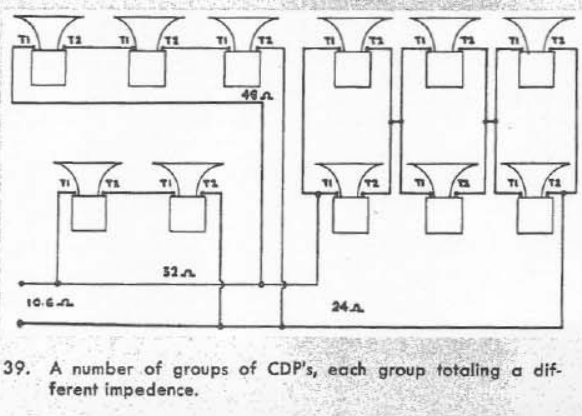
38A. Multiple CDP's in series.



38B. Multiple CDP's in parallel.



38C. Multiple CDP's in series parallel.



39. A number of groups of CDP's, each group totaling a different impedence.

Appendix

Constant Voltage Distribution Systems—The 70-Volt Line

A problem which arises when a sound installation is performed by a contractor is that of matching multiple speakers to the amplifier. The engineers of the amplifier manufacturers, through the RTMA, have simplified the rather involved calculations in adopting what is known as the *Constant Voltage System*.

This is the way the system works: The building codes generally limit the amount of voltage that may be carried by a line not in conduit. By providing a secondary tap of the proper impedance on the output of the amplifier transformer which will deliver 70.7 volts at the rated power of the amplifier, controlling the primary impedance of the various matching transformers in the circuit will determine the wattage delivered to the respective speakers.

On modern matching transformers these primary impedance taps are labeled in watts as well as in ohms. (See *Fig. 22* showing the Model 878 Matching Transformer).

Where alternative matching transformers are used labeled on the primary taps only in ohms, the following chart will show the tap to be used for the selected wattage to be delivered to the speaker voice coil. *Fig. 37*.

The mathematics are based on the following formula:

$$Z=\frac{E^2}{P} \text{ of Transformer Impedance}=\frac{(\text{Output E})^2}{\text{desired power to be delivered to loudspeaker (s)}}$$

In the 70-volt system this is simplified to:

$$\text{Required Transformer Impedance}=\frac{70.7^2}{\text{desired power}}$$

$$=\frac{5000 \text{ approximately}}{\text{desired power}}$$

For a 141-volt line substitute:

$$\frac{141^2}{\text{desired power}}$$

or

$$\frac{20{,}000 \text{ approximately}}{\text{power desired}}$$

Through these means, by simply deciding on the power desired for each loudspeaker, and making certain that the amplifier will deliver at least the total power required, the matching transformers with proper taps connected may be paralleled across the 70-volt line with no further consideration of impedance.

It is important that the secondary of each matching transformer be terminated by the appropriate voice coil impedance, although mismatches up to 20% are permissible.

Series Parallel Connections of the CDP's

Figure 38A shows how two or more *CDP* units may be connected in series. The individual impedances are additive; thus, the total impedance for the circuits shown is 32 ohms and should be matched to a 32-ohm tap on the output transformer if one is provided. The next figure (*38B*) discloses the solution to the problem in case only 8 and 16-ohm taps are provided. When using two *CDP*'s in this case, they should be paralleled, thus, permitting an 8-ohm load impedance to be connected to the 8-ohm tap on the output transformer with a perfect match. The next figure (*38C*) shows how four *CDP's* may be series paralleled in order to make a proper impedance match to the 16-ohm tap of the transformer.

Quite frequently it is necessary to series parallel a large number of speakers in order to arrive at a proper amount of total impedance to equal the impedance tap available on the output transformer. When two or more sections or groups of *CDP* speakers are connected in parallel (*Fig. 39*), totaling different impedances for each group, the following formula may be employed to determine the proper tap to use on the output transformer:

FORMULA:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + R_N$$

Where R_T = total impedance

$R_1, R_2, \ldots R_N$, = individual impedances of various units or groups of units

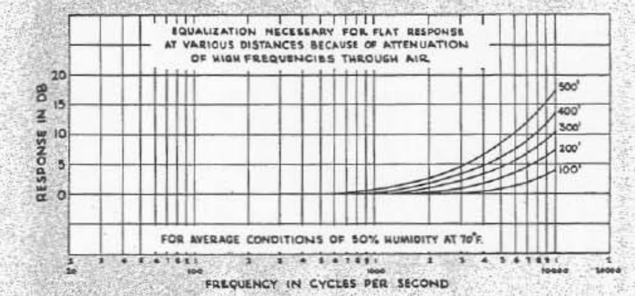
EXAMPLE:

$$R_1 = 16+16 = 32$$
$$R_2 = 8+8+8 = 24$$
$$R_3 = 16+16+16 = 48$$
$$\frac{1}{R_T} = \frac{1}{32} + \frac{1}{24} + \frac{1}{48}$$
$$\frac{1}{R_T} = .031+.042+.021$$
$$\frac{1}{R_T} = .094$$
$$R_T = 10.6 \text{ ohms}$$

Use 8 ohm tap

Attenuation of High Frequencies over Long Distances from the Projector

For average conditions of temperature and humidity, the attenuation of higher frequencies becomes a factor in the proper distribution of high quality sound in larger auditoriums and outdoor locations. Reference to the chart shown in *Fig. 40* will indicate that the problem becomes quite serious above 3,000 cycles. At 300′ the attenuation at 10,000 cycles is on the order of 10 db; this means that equalization for the far distances is required at the amplifiers. Because most amplifiers are equipped with auxiliary tone controls, this compensation can be easily made.



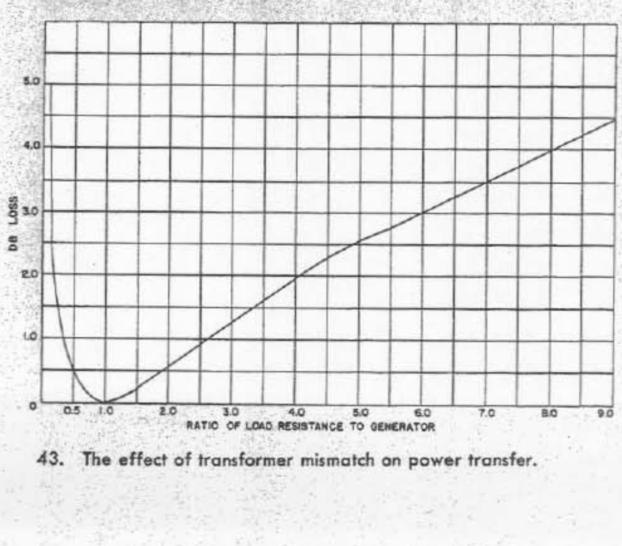
40. Equalization Chart.

WIRE SIZE (B & S)	LOAD IMPEDANCE		
	100 OHMS	250 OHMS	500 OHMS
14	1000′	2500′	5000′
16	750′	1500′	3000′
18	400′	1000′	2000′
20	250′	750′	1500′

41. Maximum length of high impedance line for 5% power loss.

WIRE SIZE (B & S)	LOAD IMPEDANCE		
	4 OHMS	8 OHMS	16 OHMS
14	125′	250′	450′
16	75′	150′	300′
18	50′	100′	200′
20	25′	50′	100′

42. Maximum length of low impedance line for 15% power loss.



43. The effect of transformer mismatch on power transfer.

For unusual conditions, such as those found in Arizona, New Mexico and Southern California, where the humidity drops as low as 20%, a more violent equalization is required above 3,000 cycles. For 6,000 and 10,000 cycles the high boost demanded is practically double that shown on the accompanying chart. 3,000 cycles remains relatively the same regardless of the change in humidity.

Because the *CDP* has the necessary extended range response with which to begin, it is susceptible to equalization from the amplifier to overcome the deficiencies in response at far distances indicated by the chart.

Wire Size vs. Lead Lengths in Lines at High Impedance

The professional installation demanding greatest flexibility, minimum losses and closer matching requires a higher impedance line. Note in the table (*Fig. 41*) that the greater distances can be handled practically with reasonable wire sizes.

Wire Size vs. Lead Lengths in Lines at Voice Coil Impedance

By series-paralleling the 16-ohm voice coils of the *CDP*'s, various impedances may be obtained which may obviate the need of impedance matching transformers. This holds true especially where the *CDP's* are mounted in a cluster, at some distance from the amplifier. Where the distances involved are several hundred feet the size of the wire leading to the voice coils is very important and the table (*Fig. 42*) indicates the wire sizes required for various distances for a maximum loss of 15%.

Series Parallel Connections

Divide the product of the impedances of the two groups by the sum of their impedances. The impedance of a four and sixteen ohm group in parallel would be four times sixteen over four plus sixteen equals 3.2 ohms.

When more than two different groups of different impedances are to be connected in parallel, the reciprocals of the individual impedances for each group should be added and then the reciprocal of the sum taken.

As a precaution in wiring large installations using many *CDP* units, an attempt should be made to use as many units in parallel as possible rather than in series. The reason for this will become obvious when it is realized that although 25 to 30 volts may be developed across the voice coil of each individual unit, the entire series may have as high a voltage to ground as several hundred volts. This constitutes an undue hazard which should be avoided if at all feasible. This holds true particularly when metallic dust in the air through the course of the years filters into the sensitive magnet gap. This dust tends in time to decrease the spacing between the voice coil and the gap structure itself and means that the higher voltages involve a danger of arcing over with possible consequent damage to the voice coil winding.

Effects of Mismatch Upon Power Transfer

The graph (*Fig. 43*) will indicate the effect of a mismatch upon power transfer. Two things will become obvious immediately upon observation:

First, the power loss is by a very large proportion much less if the high impedance of the load is connected to the lower appropriate impedance tap on the output transformer.

Conversely, a low impedance load connected to a higher impedance tap on the output transformer will result in a much greater ratio of loss. In this latter case, violent frequency discrimination takes place also in that the low and high frequencies are favored. While this is occasionally of some benefit in high-fidelity home music systems, it is a situation not to be desired where power is at a premium as in a public address installation.

Every effort should be made to properly match the speaker load to the amplifier output and a load impedance which is within 20% is generally considered a satisfactory match. In view of the ability to institute a loss factor, as shown by the chart, where less power is actually desired, a calculated mismatch may be made. In every case the sound engineer is offered two choices: One is the violent loss by permitting a high load-to-transformer impedance ratio, and a less violent loss by reversing this process. This will effectively serve as a method of regulating power levels with the equipment at hand.

◆

Attenuation of Low Frequencies for Large Halls and Highly Reverberant Locations

A very simple and practical method of attenuating the low frequencies can be effected by the installation of a series condenser of sufficient size in the line for the frequencies involved.

The procedure is simple: Simply select the frequency at which a 6 db attenuation is desired. (6 db is ¼ the power or approximately 65% "loudness"). Multiply this selected frequency times the line impedance and divide this product into 79,600. This will equal the capacity in microfarads which should be employed. For a low impedance circuit, it will be evident that this capacity will be quite large; this will be on the order of 20 to 40 microfarads according to the point at which the low frequency rolloff should start. In high impedance circuits, this capacity is relatively small. However, in high impedance circuits the voltages generated are quite high and accordingly, the working voltage of such a capacity should be 400 volts. For the lower impedances, the working voltage of the condenser can be between 50 and 100 volts. This will decrease the cost of the capacitor which can run quite high in the large values.

ARCHITECT'S SPECIFICATIONS FOR THE MODEL 848 CDP

The loudspeaker shall have a frequency response range flat within plus or minus 5 db from 175 to 10,000 cps as measured by accepted methods. The efficiency of this unit shall be 46 db as measured by the RTMA standards, or 104 db of sound pressure on the axis at 4 feet, with a tone warbled between 1,000 and 1,500 cps with one watt input. The weight of the unit shall be not more than 14 pounds in those cases where a matching transformer is required as an integral part of the assembly, and not more than 12 pounds where it is specified without the matching transformer. The unit shall have a yoke-type of mounting suitable for use with standard pipe clamp fittings.

For purposes of this specification, the angle at which the sound pressure is 10 db down from the axial sound pressure shall be used to determine the sound dispersion. Provisions shall be made for varying the sound dispersion pattern to suit specific applications.

Four adjustments for sound dispersion shall be incorporated permitting tones above 1,000 cycles to be confined in a beam of 120° or 90°. Tones below 1,000 cycles shall permit an adjustment of the beam by turning the horn vertically or horizontally 120° and 90° respectively. In combination, these two adjustments will effect the three dispersion patterns mentioned. This requires that two horns be employed, one for the high frequency tones above 1,000 cycles and one for the low frequency tones below 1,000 cps, and further that the high frequency horn be capable of a rotation of 90° within the low frequency horn. It shall also be possible to tumble this unit down a flight of ten steps with no physical or electrical damage effecting its operation. The unit shall also be capable of complete submersion in water during operation, and continued operation after withdrawal with no damage to the mechanism.

The driver unit shall be capable of the application of a 60 cycle tone at 25 watts of power, without the horns attached, for a period of three days continuous operation without failure to the mechanism. The diaphragm and moving coil assembly shall be field replaceable with common tools and require no adjustments in the effecting of this replacement.

PERFORMANCE SPECIFICATIONS

RATED INPUT POWER: 25 watts

INPUT IMPEDANCE: 16 ohms

CROSSOVER FREQUENCY: 1000 cps

FLAT RESPONSE RANGE: ± 5 db from 175 to 10,000 cps

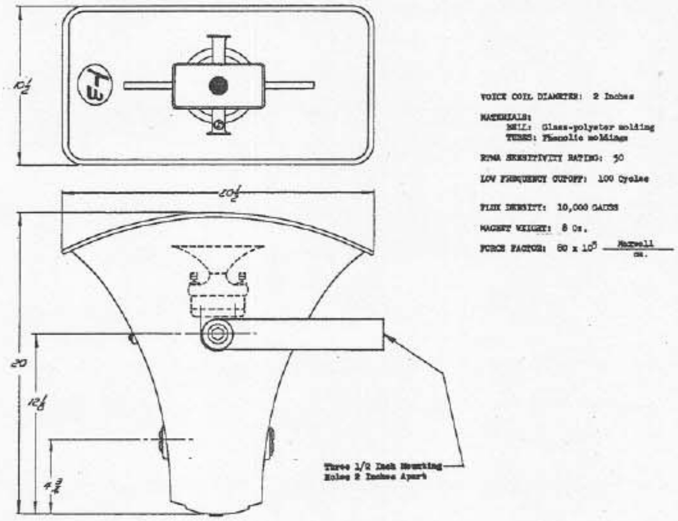
FOUR POLAR PATTERNS: 120° in vertical mounting and 90° dispersion in horizontal position. With HF horn set horizontally and LF horn set vertically, Dispersion is 90° above 1000 cps and 120° below 1000 cps. *Figures 10, 11, 12.*

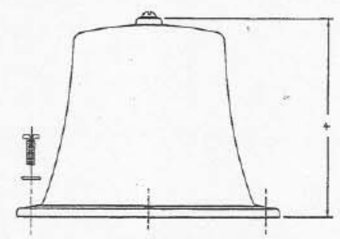
PHASING: A positive voltage applied to the voice coil terminal *T-1* will cause the diaphragm to move forward, or away from the magnet and towards the front of the Projector

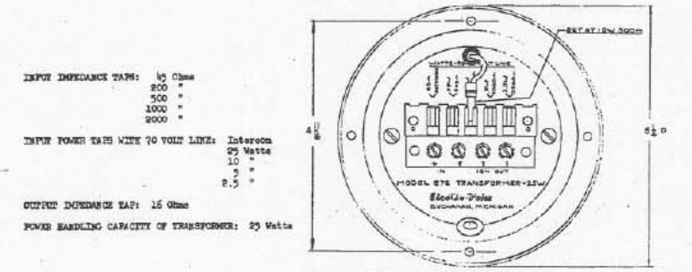
PHYSICAL SPECIFICATIONS

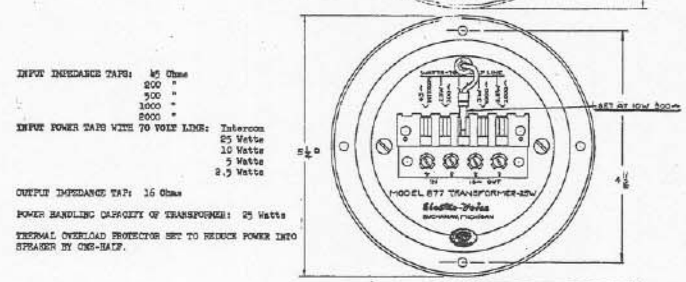
DIMENSIONS: 10½″ wide at mouth by 20½″ high at mouth by 20″ deep overall

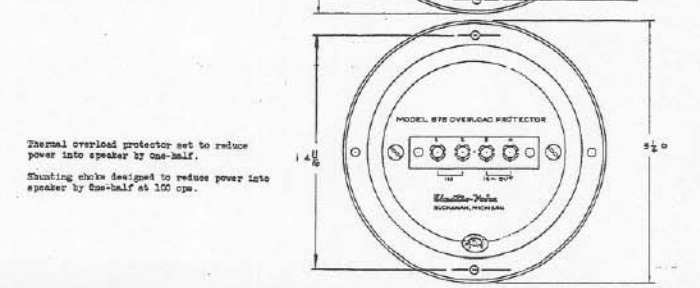
WEIGHT: 12 lbs. net; 15 lbs. shipping







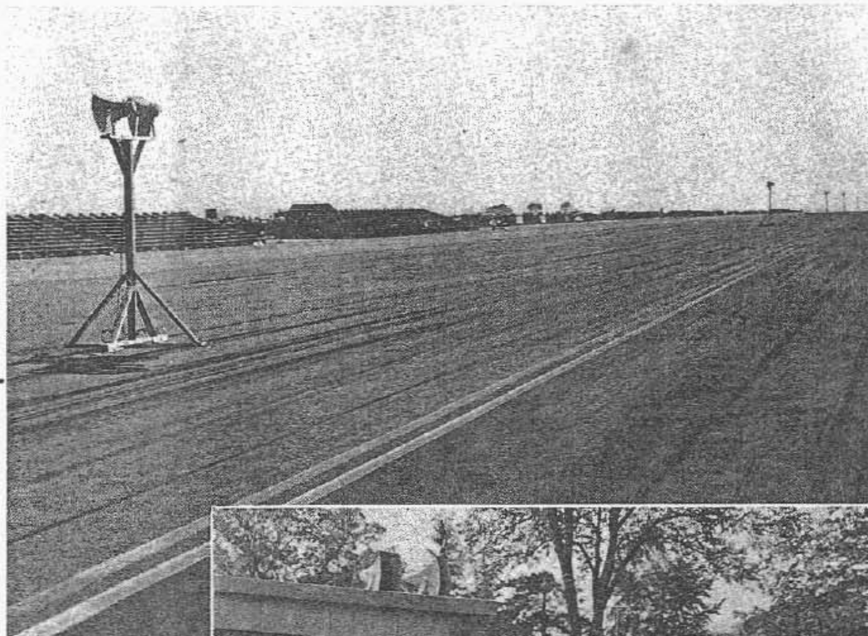


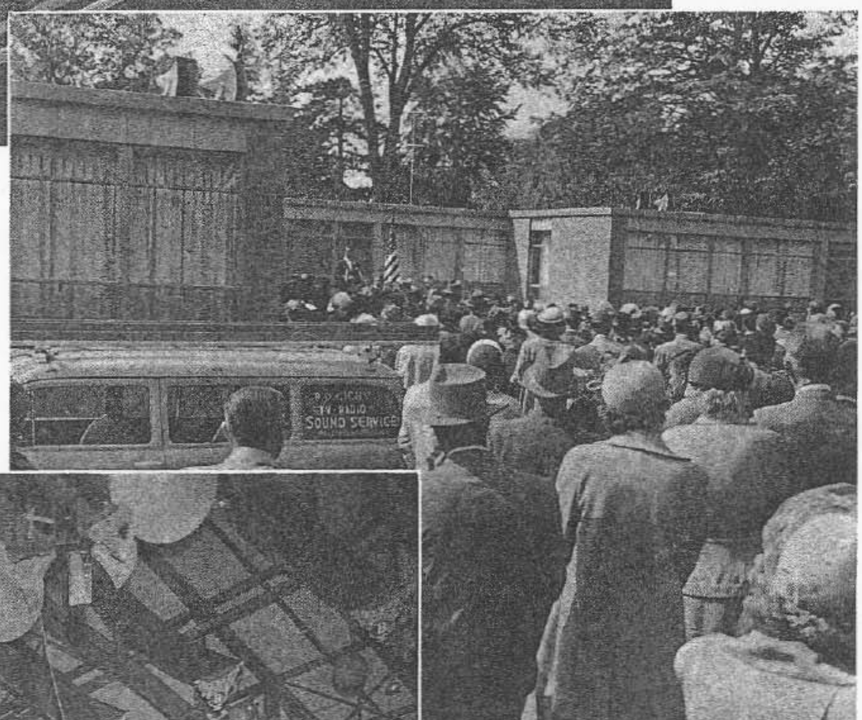


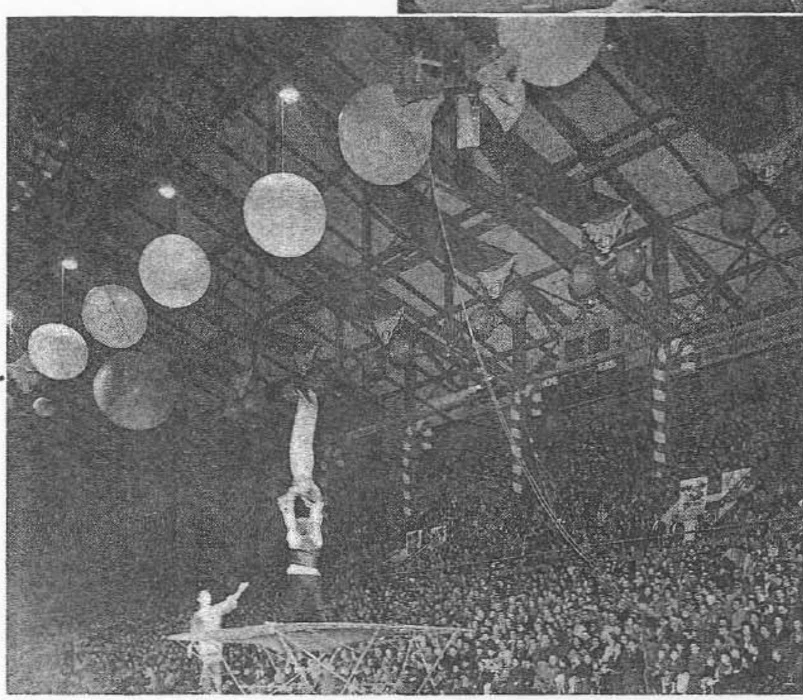
COMMENTS FROM CDP USERS—

Type of Installation	Comment
Motion picture theatre	"... far superior to any other that I have seen or heard, for my type of work ... they cannot be surpassed."
Dancing area and swimming pool	"... a very great need for this type of speaker—congratulations."
Music broadcasts in park	"... a saving in both time and money."
Golf course P.A.	"the wide angle of sound distribution is amazing."
Outdoor religious services	"I am well pleased beyond my expectations."
Drive-in	"With 4 speakers—excellent uniform coverage of 500,000 square feet or more at low output ..."
Soap box derby	"... is the top speaker of the year."
Motor speedway	"... installed 11 CDP speakers at ... Motor Speedway. The results were excellent."
Church tower	"... it has a brilliant reproduction unexcelled ... especially for church chimes."
Auditorium	"Two speakers in our school auditorium gave perfect sound control ..."
Service gymnasium	"... This building had poor acoustics and extreme echos. The former system presented serious regeneration and feedback. Your projectors ... were extremely satisfactory and for the first time everyone extended congratulations on the sound."
Interior P.A. Installation	"Marvelous development in voice range projection ... gives excellent performance in highly reverbatory areas."
Restaurant	"Particularly pleased with good coverage at low volume. Used for background music."
Packing house	"Very good"
General P.A.	"Units have met all our needs to date."
Speedboat races	"The noise level is terrific with eight boats running. We covered the pits and spectator area with six CDP's on three tripods dividing the space into three equal sections. These were driven by a ... fifty watter fed by an E-V 636 on the judges stand. The area covered actually measured 500′ long by 100′ deep along the shore. The CDP's were run at a very high level to combat the noise, of course, and at no time was there any distortion or blasting. The bass was not attenuated at all as it seemed to lend body to the sound ... CDP's become more and more astounding each time we use them. This was the clincher for us and we are now completely sold on them for all purposes."

CDP's IN USE—







THE COMPOUND DIFFRACTION PROJECTOR

By LOUIS S. HOODWIN
Senior Engineer, Speaker Design
Electro-Voice, Inc.

Electro-Voice®

ELECTRO-VOICE, INC., BUCHANAN, MICHIGAN

The Compound Diffraction Projector*

Louis S. Hoodwin
Electro-Voice, Inc., Buchanan, Michigan

A NEW HORN-TYPE loudspeaker has been developed to provide improved reproduction in public address and multiple-channel loudspeaker installations. The name of this unit is the compound diffraction projector (CDP). In order to determine how well it fulfills its design objectives, it is necessary first to determine the qualities desired in public address loudspeakers and the extent to which previous units possessed these qualities.

Although the qualities desirable in a public address loudspeaker will depend on the specific application of the loudspeaker, general requirements may be obtained by considering average applications and the demands those applications make on the five measurements of loudspeaker performance: efficiency, frequency response, polar distribution, distortion, and power handling capacity. To obtain a true picture of a loudspeaker's performance, all these measurements must be considered concurrently.

EFFICIENCY

Although a comparatively inefficient cone-type loudspeaker driven by 4 or 5 watts of audio power will produce more sound level than is usually desired in the average living room, most public address installations require relatively high sound levels and subsequently more efficient loudspeakers. Because of its relatively high efficiency, the horn-type loudspeaker is very widely used in the public address field.

Since it is generally not the purpose of a loudspeaker to produce just noise, in measuring efficiency more than just loudness must be considered. The true measure of the efficiency of a loudspeaker is the degree to which it reproduces intelligible speech and/or pleasing musical sounds at the position of the listener with a certain amount of audio power available. Therefore, if two loudspeakers are receiving the same speech signal and one is 3 db louder than the other but provides only 70% intelligibility, whereas the other provides 85% intelligibility, the loudspeaker with the lower acoustic output is for all practical purposes the most efficient. Sound level measurements for efficiency usually are made on the axis of the loudspeaker, using a single frequency or a restricted frequency range. Such measurements alone do not indicate the ability of the loudspeaker to produce sounds at the position of the listener, if the listener is off the axis of the loudspeaker. Neither do such measurements indicate the frequency and polar responses of the loudspeaker or the amount of distortion, factors which must be considered in determining the usefulness of the signal. Efficiency is determined not by axial loudness alone but also by frequency response, polar distribution, and distortion.

FREQUENCY RESPONSE

According to French and Steinberg,[1] a frequency range from 200 to 7000 cps is required for maximum speech intelligibility. The same authors show that the intelligibility index is lowered 20% by limiting the high-frequency response to 3500 cps. Good music reproduction requires a greater frequency range, particularly in the bass end. In some instances it is necessary to reduce the bass response of a system to prevent feedback or masking in very reverberant locations. But in order for a loudspeaker to be useful in the greatest number of applications, it should provide as wide a frequency range as possible within the limits of audibility. If there is need for limited or augmented frequency response at either end of the spectrum, it should be provided by the amplifier tone controls where such control is relatively easy to obtain. The best that should be expected of a loudspeaker is that it should have a frequency response that will require a minimum of equalization yet have sufficient frequency response to be equalized. In order to understand what is implied by "sufficient frequency response to be equalized," consider a case where an attempt is made to obtain maximum intelligibility by maintaining flat response out to 7000 cps, using a loudspeaker with a response that is 40 db down at 7000 cps and an amplifier that can provide 20 db of treble boost. In this case, equalization will be useless and the desired result will not be obtained. On the other hand, if the loudspeaker is down less than the available equalization, equalization may be used to good advantage.

POLAR DISTRIBUTION

In some cases it is necessary to project sound over a very great distance where the arc subtended by even a small angle will be large enough to cover the audience. Under such conditions, wide polar response is neither necessary nor desirable. But in the great majority of installations, the loud-

* Presented at the Fifth Annual Convention of the Audio Engineering Society, New York, October 14-17, 1953.

[1] N. R. French and J. C. Steinberg, *J. Acoust. Soc. Amer.*, 19, 90 (1947).

Reprinted from the Journal of the Audio Engineering Society, Volume 2, Number 1, January 1954.

speaker is relatively close to the audience and the outside limits of the audience make quite a large angle with the loudspeaker. This is especially true in industrial paging and music systems. A polar distribution of 120° is generally adequate in such cases.

The usual axial frequency-response measurements are virtually useless for predicting the performance of a loudspeaker without knowledge of polar response, unless the listener expects to be situated only on the axis in an anechoic chamber or in free space—two conditions which are seldom encountered. Polar measurements are essential in determining what frequency response each listener will hear in various parts of the audience. These measurements must also be considered in determining the total energy output and efficiency of the loudspeaker.

POWER HANDLING CAPACITY

There are two methods of determining power handling capacity. One is based on a maximum permissible distortion; the other is based on the physical strength of the unit. Both methods should be used concurrently, since units with high distortion and good physical strength and those with low distortion and poor physical strength are both very limited in power handling capacity. It is also imperative to consider efficiency at the same time as power handling capacity. To illustrate by an extreme case, if a "permanent magnet" loudspeaker were made with no magnet at all, there would be virtually no diaphragm movement and the diaphragm would last indefinitely. Without diaphragm movement there would be no distortion. The coil assembly could be made to dissipate a large quantity of heat by winding the coil with nichrome wire on an oversized metallic coil form. Such a loudspeaker would have a tremendous power handling capacity when determined by distortion and physical strength requirements alone.

A NEW PUBLIC ADDRESS HORN LOUDSPEAKER

In order to fulfill the above-mentioned requirements in frequency response and polar distribution with good efficiency and power handling capacity and low distortion, a new loudspeaker called the compound diffraction projector (CDP) has been designed. But, in order to comprehend the degree to which the CDP is an improvement in the loudspeaker art, it would be best first to consider the advantages and disadvantages of the horn loudspeakers which were available before its advent.

STRAIGHT TRUMPET

The straight trumpet is the simplest type of horn loudspeaker. Its low-frequency response is determined by its rate of flare and mouth area. Low-frequency response requires a very gradual flare, and the mouth diameter of a circular horn must be one-fourth to one-third the wavelength of the lowest frequency to be reproduced to prevent reflections. For good bass response with small diaphragm driver units, these horns become quite long and unwieldy. A typical horn having a 115-cps cutoff is about 6 ft long without the driver unit, and has a 30-in. diameter mouth. The high-frequency output of the trumpet is usually limited only by the response of the driver unit. But, in cases where the walls of the horn have an appreciable absorption coefficient, a long horn may produce drastic attenuation of the higher frequencies.

The polar response of a straight trumpet narrows as the frequency increases, owing to the effective increasing ratio of radiator size to wavelength. Large trumpets produce narrower polar patterns than small trumpets. Therefore, if an installation requires a wide distribution of sound with level requirements which should necessitate the use of only one loudspeaker, a person making the installation using only straight trumpets must use either a very small trumpet with a resultant loss of the bass response essential for good quality, or a multitude of large horns which involves a considerable expense. Most attempts to obtain wide coverage with a few large trumpets result in either uncomfortable loudness for those who are near the axes of the units or unsatisfactorily low level for those who are situated off the axes. (The polar curves of a re-entrant horn, Fig. 1, are typical of the polar curves obtained from a straight trumpet of similar size.)

One of the most important sources of distortion in a horn

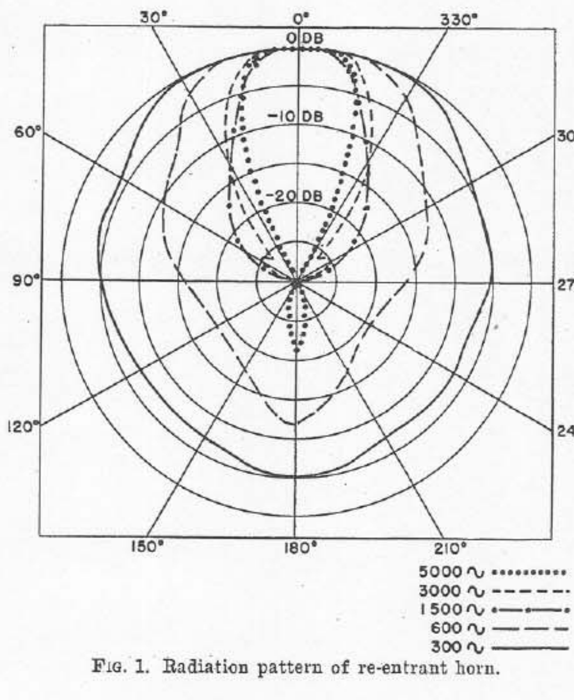


FIG. 1. Radiation pattern of re-entrant horn.

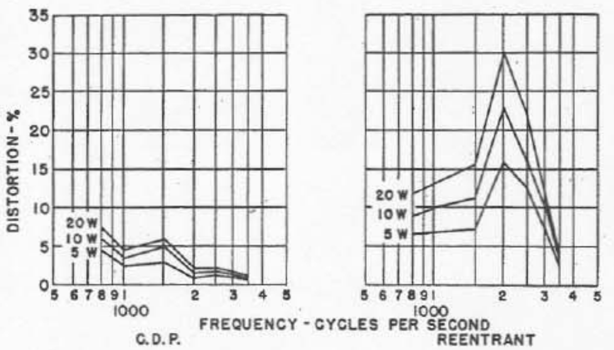


FIG. 2. Harmonic distortion curves of re-entrant horn and compound diffraction projector.

loudspeaker intended for high-level reproduction is due to the great compression and rarefaction of the air at the throat of the horn and the nonlinearity of the air, resulting in the creation of even-order harmonics. This distortion increases with both the sound intensity and the ratio of the frequency reproduced to the cutoff frequency.[2] From the foregoing it may be seen that large horns with low rates of flare exhibit more of such distortion than small horns. This is one of the reasons in favor of the use of multiple-channel loudspeaker systems. (The distortion curves of the re-entrant horn shown in Fig. 2 are also typical of the distortion produced by a straight trumpet of similar bass cutoff.)

MULTICELLULAR HORNS

The multicellular horn was developed to provide a better polar pattern than that available from the straight trumpet. These units actually consist of a cluster of straight trumpets coupled to one or more driver units through a common throat. The polar responses are limited only by the configurations of cells. But when many cells are joined, a constriction is often formed by the throats of the cells which has the effect of producing an acoustic cavity between the driver unit(s) and the cells. Such a cavity acts as a shunting capacitor which reduces high-frequency transmission, usually above 7000 cps.

The greatest disadvantages of the multicellular horn are cost, weight, and bulk. A typical horn having a 250-cps cutoff and a 3 by 6 array of cells is 28 in. high, 43 in. wide, 34 in. deep, and weighs 100 lb without driver units. A horn of this size and weight is virtually useless as portable equipment; and, since it has the relatively high cutoff of 250 cps, it provides very poor music reproduction. Because of the complexity of its construction, this unit costs around $150.00. These horns are used with separate low-frequency reproducers for high-quality installation; but where only speech reproduction is desired or where the acoustics of the location prevent the use of bass frequencies, they are often used by themselves.

RE-ENTRANT HORNS

Re-entrant horn loudspeakers have been the most extensively used reproducers for public address installations. By using a folded air column, they provide good bass response in a unit that is a fraction of the length of a comparable straight trumpet. But they still suffer from the same disadvantages of narrow polar distribution and high harmonic distortion found in straight trumpets. An additional fault of the re-entrant horn is that it reduces high-frequency transmission by cancellation in the air column when the dimensions across the bends in the air column are of the same order of magnitude as the wavelength of the sound. In the average re-entrant horn, this begins around 3500 cps.

Since the re-entrant horn is so widely used, data obtained with a typical horn are compared in this paper with the CDP data. The horn and driver unit combination used to obtain the data published here is one of the largest selling combinations in the re-entrant horn field at the present time. The horn has a 150-cps cutoff and a circular bell diameter of 20 in. The air column length is 42 in., and the over-all length with the driver unit is 19 in. Its weight is 13 lb.

THE COMPOUND DIFFRACTION PROJECTOR

The compound diffraction projector (CDP) was designed to fulfill the need for a light, compact, inexpensive public address loudspeaker which can provide a widely dispersed, high-quality signal. The CDP consists of two horns which are coupled to opposite sides of a single diaphragm. Each horn is designed for optimum reproduction of a specific frequency range. A small tweeter horn is used for high frequencies, and a re-entrant horn is used for the low frequencies. Figure 3 shows the physical arrangement of the CDP. It is 20 in. long over-all, including the driver unit, and has a 10¾-in. by 20¾-in. rectangular mouth. The total

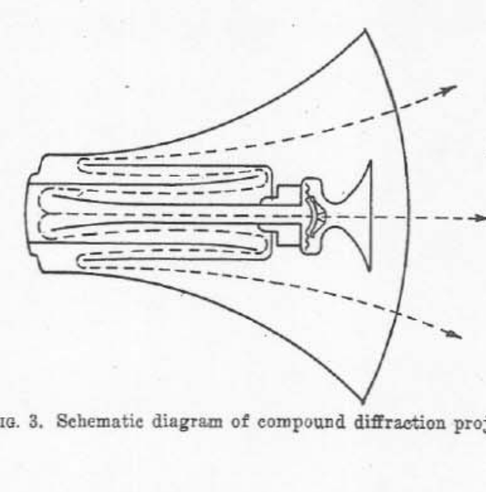


FIG. 3. Schematic diagram of compound diffraction projector.

[2] F. Massa, *J. Acoust. Soc. Amer.*, 8, 130 (1936)

weight with a driver unit is 12 lb. The use of four air column sections in the re-entrant horn permits mounting the driver unit and tweeter horn in front and also provides a longer air column length than can be obtained from three-section re-entrant horns of comparable over-all dimensions.

For greatest sound output, the impedance presented to a diaphragm by a horn should equal the mechanical impedance of the diaphragm. Generally, diaphragms are mass controlled for most of their frequency range, and, therefore, the mechanical impedance increases with frequency. The impedance presented to the diaphragm by the horn also increases as the size of the horn throat is reduced. Therefore, a smaller throat should be used for high-frequency reproduction than for low-frequency reproduction. The throats of the two horns used in the CDP are chosen for maximum output in the frequency range in which each horn operates. Since the frequency range is divided between two horns, the throat dimensions represent less compromise than in the case of a single-horn loudspeaker.

The crossover between the woofer horn and the tweeter horn is obtained by entirely acoustic means. At frequencies well below the cutoff of the tweeter horn, only the woofer is radiating, since the radiation resistance of the tweeter is negligible. At frequencies above the crossover point, a cavity between the diaphragm and the throat of the woofer horn, which acts as a capacitor shunted to ground, effectively decouples the diaphragm from the horn; meanwhile, the tweeter horn is being operated above its cutoff and is therefore radiating. Figure 4 shows the axial response curves for the re-entrant horn and the CDP.

In order to obtain a maximum of bass response with a minimum of size and expense, the re-entrant horn of the CDP is made with a 100-cps taper and a comparatively small mouth. If a single projector is used by itself away from building walls and other surfaces, its bass response is comparable to that of a re-entrant horn of similar size down to the point where the response of the re-entrant horn starts to drop off rapidly. But the response of the CDP continues below this point, owing to its lower rate of flare. If it is desired to take full advantage of the 100-cps taper, the CDP may be mounted with its mouth next to a wall or ceiling or on the floor or ground, wherever a surface may effectively increase the area of the mouth. This permits the person who makes the installation to utilize the acoustic loading properties of the location. When added bass response is desired in open space (mounting on poles, hanging by wires, etc.), it may be obtained by mounting two or more CDP's close to each other in order to obtain mutual loading. Since the mouths of the CDP's do not have to be in the same plane to obtain mutual loading, the array may also be arranged to provide improved polar distribution.

One of the most noticeable improvements in the CDP over the re-entrant horn is its extended high-frequency response. By avoiding energy-cancelling re-entrant sections and by using a horn which is specifically designed for high-frequency reproduction, the high-frequency response of the CDP is made comparable to that of a good-quality tweeter. A comparison of the response of the re-entrant horn and the CDP between 1000 and 3000 cps will show that the re-entrant horn is about 4 or 5 db higher in level than the CDP. But, since these are axial response curves, before judgment is passed on the relative efficiencies of the two units, polar responses must be considered.

Figure 1 shows the polar response of the re-entrant horn. It may be noticed that the polar response is good for the frequencies having wavelengths that are large compared to the diameter of the horn mouth. But, as the wavelengths become shorter, the sound output is concentrated more on the axis. These curves indicate why the straight trumpet and the re-entrant horn are best adapted only for applications where it is necessary to project sound over long distances or to a very small audience. But even in these cases, there are the factors of limited high-frequency response in the re-entrant horn and distortion in both the straight trumpet and re-entrant horn that make them undesirable.

Both horns in the CDP are designed to utilize diffraction in order to spread the sounds they reproduce. In this manner they resemble the familiar diffraction slit used in optics. When the width of a slit is small compared to the wavelength of the energy that passes through it, that energy is dispersed greatly in the direction of the short dimension, or width. Therefore, the mouths of both horns are made with one dimension which is short compared to the wave-

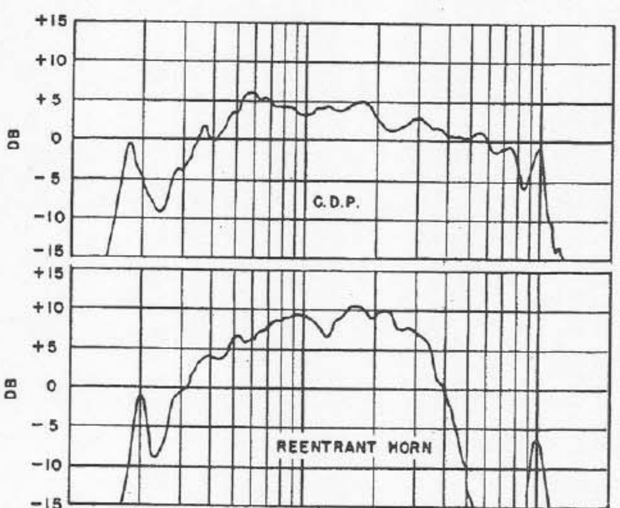


FIG. 4. Axial frequency response curves of compound diffraction projector and re-entrant horn.

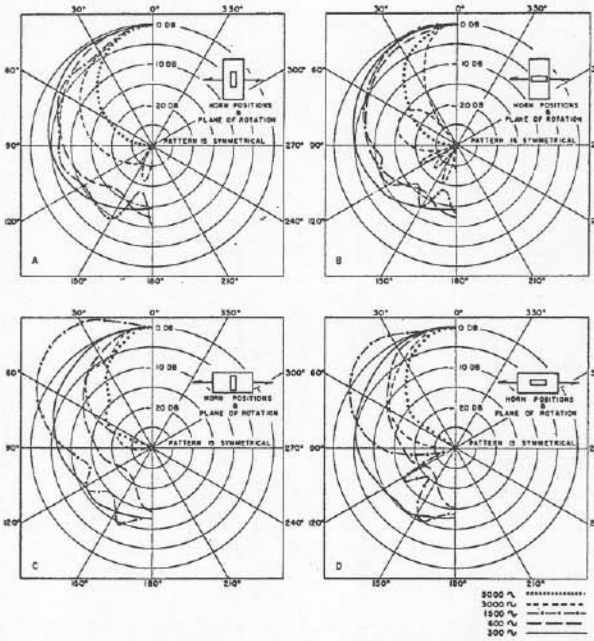


FIG. 5. Polar response patterns of compound diffraction projector.

length of most of the frequencies it passes. In order to provide the greatest versatility, the CDP is constructed so that the bass horn may be mounted with its short dimension horizontal or vertical and the tweeter horn may be rotated to any position. By varying the positions of the two horns, polar patterns for various applications may be obtained. Figure 5A shows the horizontal polar response with the short dimensions of both horns horizontal. This arrangement provides the smoothest and most uniform polar pattern and is best for general usage. By rotating the tweeter horn 90°, the pattern shown in Fig. 5B is obtained. The narrow 3000-cps response is useful in preventing feedback when a microphone must be used in front of a projector. In both of the above sets of patterns, since the woofer horn was not rotated, the 300- and 600-cps patterns did not change. Unusual high-frequency patterns are observed in the plane of the long dimension of the woofer horn. Figures 5C and 5D show two such patterns. The large high-energy loops are due to widely spread sound from the tweeter horn which is reflected from the inner walls of the woofer horn and arrives at the point of measurement in phase with sound that has come directly from the tweeter horn. Responses of this type are desirable when it is necessary to project sound into the corners of a room from a single projector mounted in the middle of the opposite wall, or where the audience is in a rectangular configuration.

Reference to the polar patterns of the CDP compared to the re-entrant horn shows the absurdity of trying to determine the efficiency or usefulness of a loudspeaker from the axial frequency response only. The axial response curves show about a 4- to 5-db advantage for the re-entrant horn compared to the CDP at 3000 cps. But in all the polar patterns, the CDP is only about 10 db down at 3000 cps 60° off the axis whereas the re-entrant horn is down about 25 db. An even greater difference exists at 1500 cps. When total energy output is considered, the CDP is more efficient than the re-entrant horn.

As mentioned previously, high intensity reproduction with a horn at frequencies that are far above the cutoff frequency of the horn will result in a great amount of distortion. In Fig. 2 are plotted the percentages of harmonic distortion *vs* frequency for various amounts of input power for the re-entrant horn and the CDP. Although both the second and third harmonics were used for these measurements, the distortion consisted mainly of the second harmonic, as predicted by theory. As an added check on the theory, a driver unit which had less efficiency in the frequency range measured was tried in the re-entrant horn. The distortion was noticeably reduced. From the foregoing it is shown to be impossible to obtain low-distortion, high-level reproduction in the middle and high frequencies with the usual size of re-entrant horn or straight trumpet. This same distortion will also be produced by large multicellular horns. Since with a CDP the high frequencies are reproduced with a horn that has a relatively high cutoff, such distortion is kept to a minimum. The gradual reduction in distortion with increase in frequency is due to a reduction in pressure at the throat of the horn caused by increasing diaphragm impedance and decreasing shunting impedance of the chamber in front of the diaphragm.

Distortion measurements were made using a CDP at 20 watts at various frequencies from 2000 to 3000 cps. These measurements indicated about 2% distortion. The driver unit was then removed from the CDP and placed on a re-entrant horn (150-cps cutoff), so it was driving the horn from the "high" end of the unit. Distortion measurements were again made at 20 watts between 2000 and 3000 cps. This time the distortion was about 10%.

By utilizing the acoustic advantages that can be obtained from a compound horn loudspeaker, the CDP provides a signal that has improved frequency response and polar distribution with lower distortion in an inexpensive, lightweight unit.