AUDIO SYSTEMS FOR FM BROADCASTING

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While the design of audio systems for FM broadcasting is an individual problem for each station, the author describes many basic circuit arrangements which are applicable to most cases. These may usually be adapted to the situation at hand with little modification.

WITH THE COMING of hundreds of new FM broadcasting stations will be the construction of an almost equal number of new studio layouts. A number of these installations will be made by individual owners or organizations that have had long experience in the broadcast business, while a great many will be made by those to whom broadcasting is a new venture. It is for the possible assistance to the newcomers in the field that this article is being prepared.

Designing an audio system for FM broadcasting is an individual problem with each broadcast station that can be solved in its entirety only by the management and the engineering staff of the individual stations. Although many items of the system design are common to all stations, an almost equal number are found to be different from station to station. This variance is due to differences found in programming, in policy, in local conditions, size and number of studios, and the past experience of the chief engineer. It is impossible to lay out in a single article a design of an audio system that will fit all the conditions of all the new layouts. However, the basic consideration and circuits of audio systems found to be applicable to the most cases will be presented. These can be applied with the necessary modifications to fit the functional requirements of the individual station.

While the actual audio equipment employed in an FM system must receive careful attention, it in itself is not the most important part of the system and it is not the part of the design which is hardest to solve. Reliable manufacturers of broadcast equipment now have time-proven equipment and components that will meet FM requirements with regard to performance when properly assembled. However, the most carefully laid out system of the best components, meeting all functional requirements of operation, having the flattest frequency response, the lowest possible distortion and the least amount of hum and noise will fall absolutely flat on FM performance if the acoustical design of the studio is not correct. Although it is not the intent of this article to go into studio design, it is felt that a mention of its importance should be made before going into audio circuits. Studios must be quiet, must have a cer-

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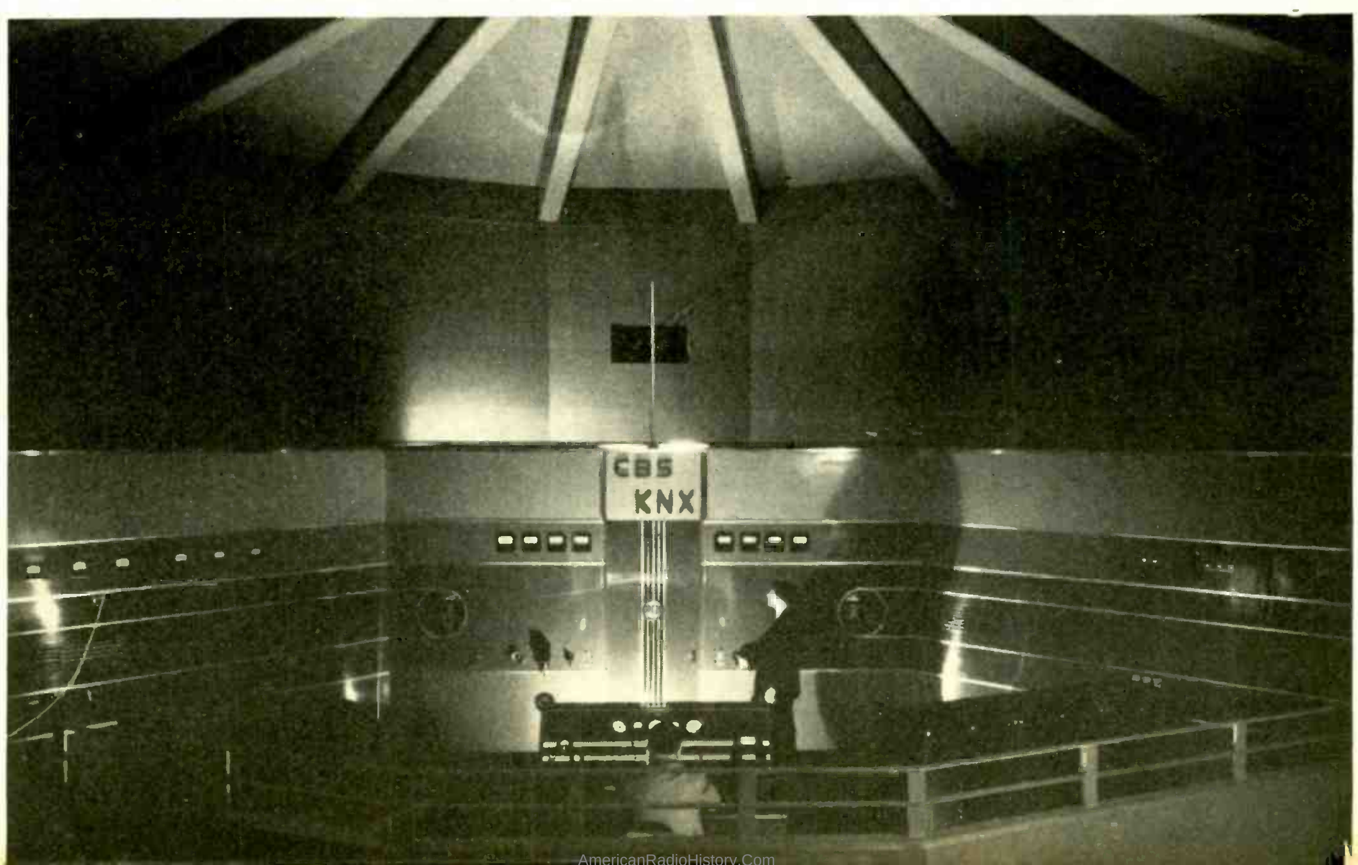
All audio and transmitter controls are centralized on the center control console of the CBS-KNX plant shown.



tain reverberation time and frequency response, must have certain dimensional ratios, and must have minimum volume per performer, and there are other important factors.

Studio Design

For the actual design of the studios one should enlist the services of an acoustical consulting engineer who has had experience in the design of FM studios. Ideas on the arrangement of studio control rooms can be obtained from several of the manufacturers of broadcast equipment and by visiting other broadcasters who have up-to-date studios. The architect employed to make up the plans for the studios should work closely with the acoustical engineer. Too much stress cannot be laid upon the importance of arriving at the right design before construction work is started and the importance of attention to every detail during the building of the studios. Every dollar spent in properly designing the studios will be a good investment.

Starting at the assumed condition that the new station has decided rather completely upon the number and size of studios that will be required for its programming, that the studio site has been selected and that adequate design for the studios is being prepared, an outline of circuits and equipment will be discussed. It is also quite safe to assume that the bulk of the new FM stations will decide on three studios as being sufficient for their operation; about three-fourths of the remainder will have five studios and the balance will run between eight and ten studios.

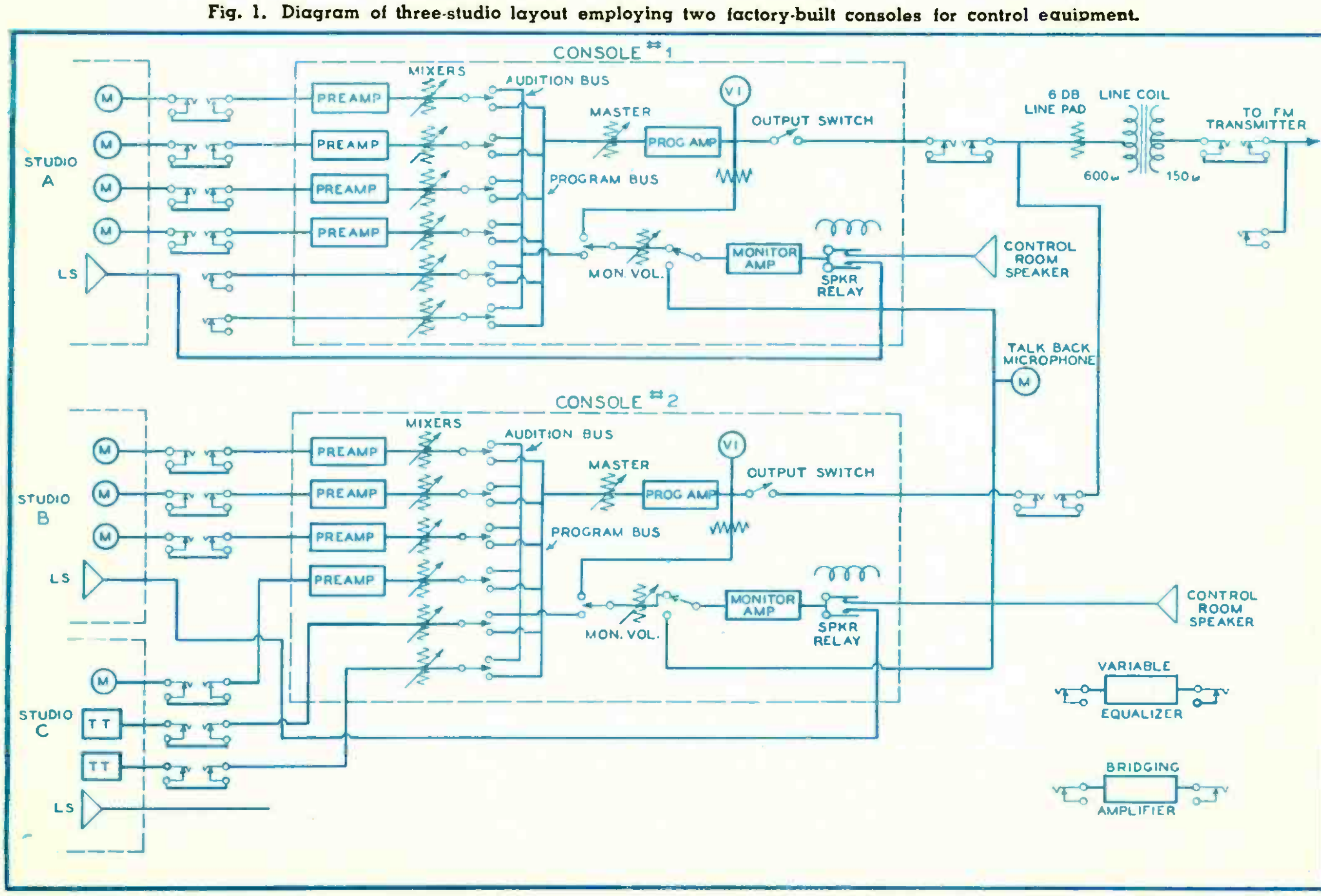
A distinct difference exists between the equipment required for a single control room—three studio layout, the five, and the eight-to-ten studio plant. For the three studio—single control room it would be well for economic reasons for the new station to consider the purchase of completely assembled consoles that are available from several manufacturers. These consoles have been thoughtfully designed and improved over the past five years and are capable of handling practically all of the requirements of the small three studio station. Four to six microphone inputs are usually available on these consoles, and an additional mike circuit for the announce booth is obtainable by a switching arrangement. Facilities for turntables, remote programs, auditions, cueing, signal lights and talk-back are available. Arrangements for emergency operation in case of main amplifier and power supply failures are provided in most cases. The fact that such units are built in quantities on production lines makes their cost run about one-half to one-third the cost of a custom-built equipment that would do the same job.

A word of caution should be injected concerning the use of these consoles. As built, they will give satisfactory performance in all functions for which they were designed. As is often the case, a broadcaster comes across an unusual condition of operation that cannot be met with the circuits available, but observes from the wiring diagram that if a certain change is made, the desired result can be obtained. Making changes in the console circuit may lead to trouble, such as an oscillation condition or a rise in hum level. Great care was exerted and much rearranging of cables was necessary in the design models to obtain stable operating conditions in consoles. Disturbing these cables should be avoided, if possible.

Three-Studio Layout

In most cases, the small three-studio layout will not require any output switching nor additional line amplifier other than that supplied in the console. However, a bridging type of amplifier capable of delivering about a plus 24 dbm output and having approximately 40 to 50 db gain will find many uses around the station; such as, feeding programs to a network, bridging the program line for a feed to a recording amplifier, or as a booster for a long re-

Fig. 1. Diagram of three-studio layout employing two factory-built consoles for control equipment.



mote line that has required considerable equalization. Another useful external addition to such equipment is a strip of jacks through which are normalled all of the inputs to the console. This will allow a greater flexibility in setups. A variable line equalizer should be employed for compensation of remote lines. This equalizer as well as the bridging amplifier should also appear on the jack strip. Care should be taken when connecting the input and output of this amplifier to the jack strip so as to allow as much separation as possible from the microphone circuits.

Figure 1 shows in block diagram form a three-studio layout employing two factory-built consoles for control equipment. This diagram shows the basic circuits of these units that are common to the several manufacturers and include several of the added features mentioned.

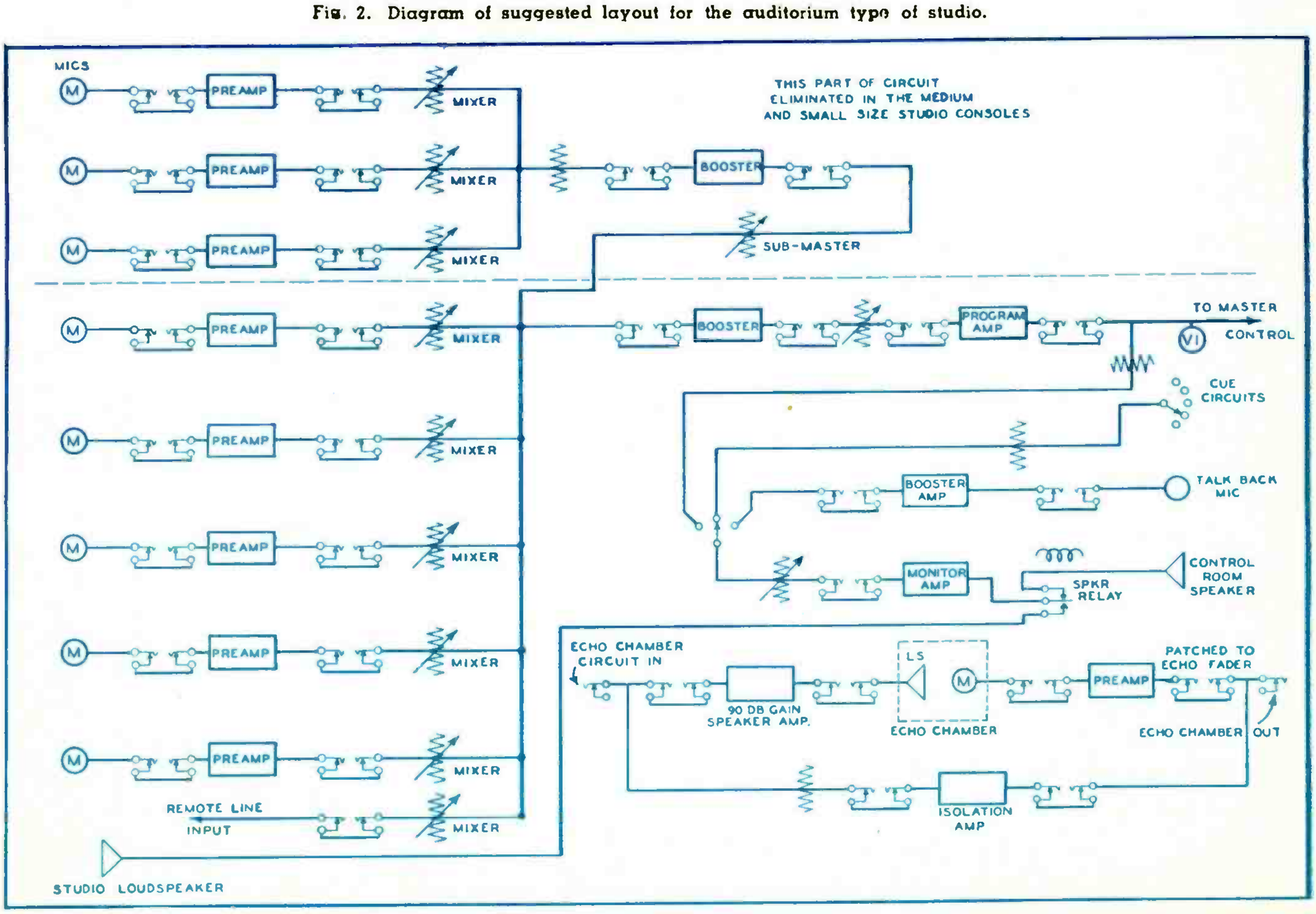
Going on to the five-studio and the eight-to-ten studio layouts, the basic difference in these two size groups lies in the output switching and added refinements as the number of studios is increased. The control consoles for each group are comparable, the only variation being in the number of microphone inputs. The usual trend is toward custome-built consoles that have only the required operational functions rather than the factory-built consoles that would have more than necessary of some features and not enough of others. Reference is being made here to the remote line and remote cueing facilities found in these consoles, which are unnecessary to the extent provided for a single studio control that operates into a master control. Also, these consoles are usually limited to five microphone inputs, while twice this number is often required for a large studio.

Console Sizes

In general, three sizes of consoles will be required for either the larger size group of studios—one to care for the auditorium type of studio, one for the small and medium-size studio, and one for the announcers' and turntable studio. As a rule, a five-studio layout will have one auditorium studio, two medium studios, one small studio, and one announcers' and turntable studio. A ten-studio layout will have two auditorium studios, four medium studios, two small studios, and two of the announcer type studios. One of the latter of these might be permanently assigned to news while the other is used for announcements and transcriptions.

Figure 2 shows in block form a suggested layout for the auditorium type of studio. Eight microphone inputs are provided. It will be noted that three of the microphone faders feed through a submaster gain control. The purpose of this agreement is to permit the individual settings of the three microphones to be made to suit the conditions of pickup of an orchestra which, during the course of the program, must be faded in and out rapidly to accommodate sketches or announcements. This fade out and in can be accomplished by the use of one control knob and with the assurance that, when faded in, that proper balance still exists. The remaining five inputs are straightforward. In addition to the eight microphone inputs, one input without a preamplifier is used to handle a remote input. The source of this remote input might be that portion of a divided program in which a speaker talks from a distant point, or it might be a sound effect patched through from the transcription studio. A conventional talkback and monitoring system is shown. Equipment necessary for one echo chamber is shown separate from the circuit of the console with the exception of the echo chamber volume control which would be part of the console. Thus the same echo chamber equipment could be used with any studio equipped with an echo control fader by patching in through trunk circuits. The input and output of the echo chamber circuit is connected by patch cords to the desired microphone

Fig. 2. Diagram of suggested layout for the auditorium type of studio.



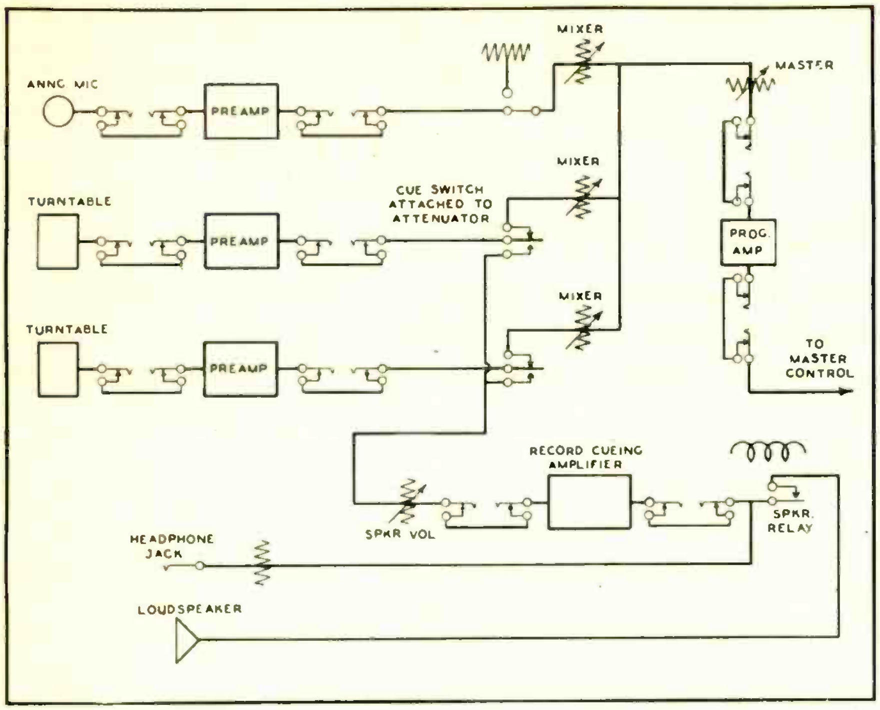
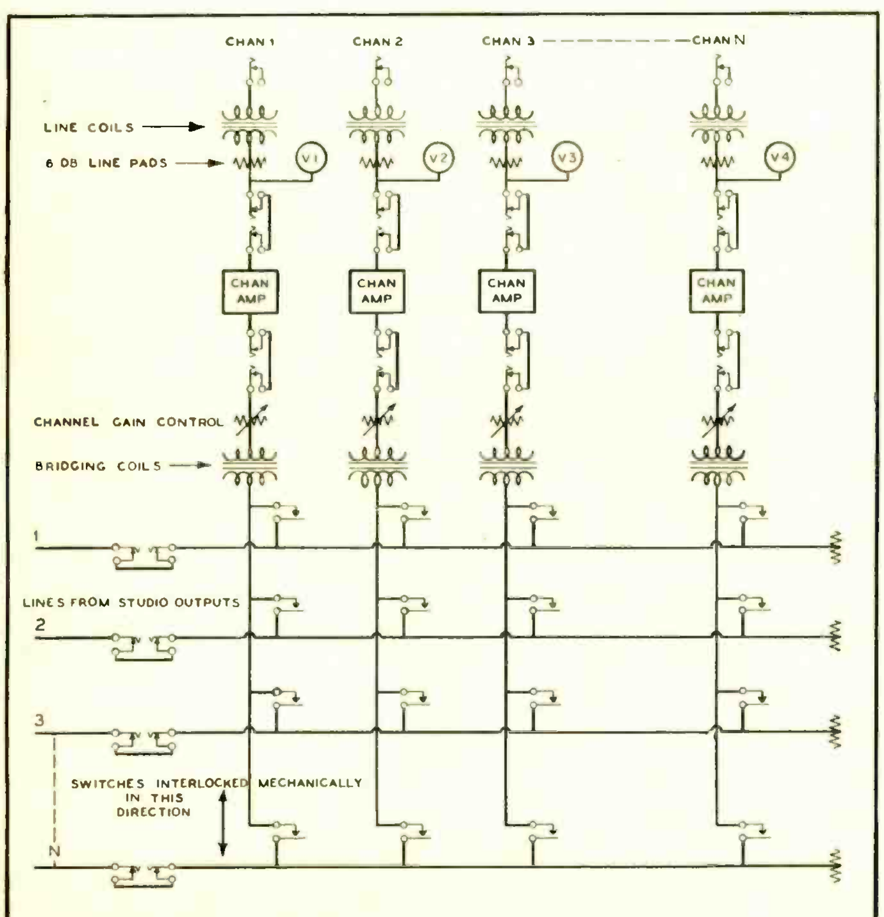


Fig. 3. Suggested arrangement for handling transcribed programs.

circuit at the jacks following the preamplifier for that microphone. For echo on the over-all program, the input and output of the echo chamber would be picked up by patch cords at the jacks following the booster amplifier preceding the master gain control. The amount of echo is determined by the setting of the echo fader mounted on the console.

Fig. 4. Diagram of master switching circuits for manual or preset relay operated systems.



The circuit for the medium and small type of studio would be exactly the same as that shown in *Fig. 2*, with the elimination of the three microphone circuits feeding into the submaster control. This leaves a total of five microphone inputs and a remote line input. All other features would be the same.

Transcribed Programs

Figure 3 shows an arrangement for an announcer and transcription studio and is intended primarily for the handling of transcribed programs. The transcriptions can be announced by the same person who operates the turntable or can be announced by another individual in an adjoining studio connected with a viewing window. Two turntable inputs and one microphone input are shown. The usual method of operation of the turntable faders is wide open when playing and closed when off. This makes for easier operation when a quick shift is to be made from one machine to another in that the operator need not be conscious of the necessity to open the fader on the coming-in machine to a definite part-way setting, but instead simply to turn the knob until the fader hits the stop. Proper level is obtained with the master gain control. Provisions are made for headphone or loudspeaker cueing of a transcription. When announcing is done in the same room with the transcription machine, an interlock between the announce microphone key and the loudspeaker should be provided. Turntable starting keys should be located on the console so as to confine the operator's motions to as limited space as possible during time of rapid operations.

Balanced Circuits

Concerning the actual type of circuits used in the consoles, it has been the writer's experience that the least amount of trouble will be had from any tendency toward oscillation, cross-talk between circuits, and failure of faders to completely cut off at all audio frequencies if balanced circuts are used throughout. Such a statement is subject to much argument pro and con; but of the twenty or more studio layouts designed by the writer during the past five years, the only ones that gave any trouble and required "fussing with" were three that used unbalanced circuits.

Another feature in console design that is subject to some discussion pro and con is whether all amplifiers and components associated with the console should be contained in the console turret and desk, or if only the operating controls should be contained in the

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console turret and the balance of the amplifying equipment and other components be mounted in a separate cabinet rack. An argument in favor of the completely self-contained unit is that installation costs are lower. Against the self-contained unit is the argument that it is harder to maintain and service. Arguments for and against mounting the amplifiers and non-operated components in a separate cabinet rack are the exact opposite. From experience, the writer prefers the separate cabinet rack for mounting of the amplifiers and jack strips. Installation is a first cost, but maintenance must go on for the life of the equipment.

While on the subject of consoles, it is suggested that utmost simplicity in circuits be uppermost in the mind of the designer. The less involved the system is of lights, switches, tricky interlocks, and devices that do not add to the functional operation of the equipment, the simpler and more straight forward becomes the cabling in the console. This will reduce possibilities of key clicks, noise and cross-talk, the absence of which is essential for good

FM operation. Microphone circuits can be closed by turning faders to the "off" position: a key is not necessary. It is easier for an operator to know that all that is necessary to open a microphone circuit is to bring up the fader. He need not concern himself as to whether or not a key is thrown. An output key on the console is another hazard and is definitely not required when switching of studios is done by a master control. The studio operator is concerned with the starting of the program and with his hands full of mixer controls might very easily forget to throw the output key. Master, on the other hand, is concerned only with the pickup of studios and the distribution of the program. Functional design should consider the placement of operational responsibilities in the proper places.

As was mentioned previously, the basic differences between the five and eight-to-ten studio layouts lie in the type of master control switching employed and added features that become necessary with the increase in the number of studios and increase in the volume of programs to be handled. For five studios it is felt that a manually operated type of mechanically interlocked push keys will suffice for master switching. With a possible maximum of three studios involving air time accuracy in switching and feeding a possible maximum of three outgoing circuits, an operator who is familiar with the equipment will not find it difficult to perform the operation with manual switching. Normally, fewer combinations of studios and outgoing circuits would be in use.

However, when eight to ten studios become involved and the number of outgoing circuits increases, it becomes imperative that an electrical interlocked preset relay system be employed. The increase in possible switching combinations that must be performed simultaneously become great enough that the operator could not accurately handle the operation in the time permitted. Using a preset relay system, the switching combinations can be set up prior to switch time and the entire setup combination put instantaneously into effect by the operation of one switch. Such a preset system could be used in the five studio layout, but would result in higher costs and more wiring complication for a feature that is not functionally required.

Figure 4 shows in block form the circuit arrangement of master switching that will serve for either the manual operated or the preset relay operated systems; the only difference being that relays would replace the switches shown in the latter case. In addition to the relays there would be an equal number of keys or an equivalent number of rotary switches to perform the presetting operation. Lights should also be employed to leave a pattern of the switching combinations set up in order that the operator may have a means of checking his work before the actual electrical switching is done.

Some of the features that become necessary with larger installations and that require thought are the number of outgoing channels that should be incorporated in the original design, and the method employed to handle program monitoring throughout the studio plant.

In the three-studio layout the opinion was expressed that one available bridging amplifier would suffice to handle an occasional outgoing feed in addition to the normal line to the transmitter. The five-and-larger studio layouts will undoubtedly be called upon regularly to make extra feeds. Many such stations probably will still have an AM transmitter to feed in addition to their FM transmitter. There are also local and national networks to consider and those special occasions in which stations feed regional interest programs back and forth. It is imperative that regularily assigned and installed equipment be available through the master switching to handle such work.

The five-studio station should have at least three outgoing channels with the fourth not representing an excessive investment. Channel 1 would normally be assigned to the FM transmitter line; channel 2 would be used to feed network; channel 3 is very convenient for feeding programs to the recording room; channel 4 would be held as a spare in case of failure of any of the other three, and as a reserve to take care of the unpredictable situations that arise. At least one spare input to the master switching system should be provided in addition to the five studio inputs.

The eight-to-ten studio plant will require a minimum of five outgoing channels and would not be overequipped with six. Of the five, one would be assigned to the FM transmitter, two for network feeds (local and national), two for recording, and the sixth as a spare. Two or three spare inputs should be provided to the master switching system.

Monitoring

Regarding monitoring, it has generally been found that the multiple cable to all monitoring points is the most economical and completely satisfactory

When our air valve is just cracked it allows a kw or so through.

The effect was very unexpected and pleasant. At full power our ears that had been calibrated at low intensity to "hear" 14 kc, could only hear up to 12 kc. We checked all the way to 24 kc, and there were no odd phenomena at all. When we came down again we again picked up at 12 kc. There was no nausea, or other pressure phenomena. While we did not check, it was obvious that if we were far enough removed or had enough sound isolation so the db level was a watt or two we would note the "4-watt nausea".

Generator Design

Figure 1 shows the side view of the generator. The black cylinder on top is an eccentric vane air motor rated 0.7 hp and 18,000 rpm-(300 rps). By the valve and gauge we can control the speed and thus the frequency. The frequency is checked against an audio-frequency standard, using a crystal for a microphone. A Strobotac is good for approximate frequency determination.

On the right hand end of the motor is the head unit. This is a "turbulent turbine", and is fed through the valve and gauged in a manner similar to the motor, so we have independent power and frequency control over the output.

Figure 2 shows a view looking at the shaft of the generator proper. The rotor is removed and several rotors are shown.

There are 80 jets on the stator, each about one-sixteenth inch square. They are equivalent to a single perfect orifice just under ⅝ inch diameter which at 90 pounds of air takes about 58 hp.

The rotor is very nice fitting, clearing the housing by one mil all around, and also having about 1½ mil clearance from the stator. This clearance is leakage, so we minimize it.

When the vanes on the rotor are lined up with the jets, we lose about 7% in leakage. When they clear the jets, we emit 80 slugs of air simultaneously. In one revolution of the rotor we release 3600 slugs, and at rated 300 rps we release 1,920,000 slugs per second, the frequency being 24,000. Each slug weighs about two-tenths micro-pound.

At low frequencies it is a simple siren taking up to 200 cfm at 60 lb. pressure. At 24 kc, however, it is much more complex, so we must accelerate the slugs to sonic velocity in about 5 micro-seconds, and that cannot be done with pressure alone. As we increase pressure the gas density increases also, we rapidly reach a limit in acceleration. So we use resonant chambers in the stator to build up a starting pressure about 3 times the static gas pressure.

At full power the gas in the resonant chambers is accelerated over 25,000 miles per second per second, or 8,800,000 G (times its own weight).

For any specific load the vanes of the rotor can be cut at an angle to give a reaction turbine effect and it will run itself, so the head alone can be used. This unit can be built in almost any size, and further development should allow operation on steam.

In any such device, however, a motor should be provided to bring it to speed above sonic range as, while it is starting up, in about 3/5th of a second you will be quite unpopular for some blocks around.

The power density is about 40 kw to the square inch, and the rotor shows no erosion in about 50 hours test even though the air filter was removed to allow dust to enter.

For low-frequency operation a crude impedance-matching horn was used, and no actual data taken on the sound level in the room. The wave shape at 800 cycles was between sine and triangular. At 12 kc it was pretty good sine, and at 24 kc was very complex, as there are many factors affecting the wave shape.

For daily experimental work, a stator with a single jet should be used, as the power density and acceleration are the same, and only about a half h-p compressor is needed. When higher powers are required, a stator with any number of holes can be used up to the full amount.

Some darn fool (the writer) put his *left* hand in the full field at 24 kc for a few seconds. The effect was that of having little scintillating hot and cold spots, rapidly alternating, over the area of skin in the field. The hand has not dropped off yet. The calculated percentage of reflection of sound energy from the flesh is about 99.98%, so apparently we do not have a death ray. Also, 24 kc is attenuated through air 6 db in 180 feet, so it does not travel too far.

This little head puts out over half the audio power of the big siren installed on top of the RCA building in New York City for air-raid warning, which delivered about 36 kw. The effect is rather pronounced in a small room.