HARMONICS and ORGAN PIPES

by DAN BARTON, Organ Builder
Illustrated by the Author

FOREWORD

Knowledge of musical acoustics, especially pertaining to harmonics, is nearly all based on theory. The definition of theory is, "A more or less plausible or scientifically accepted general principle offered to explain phenomena, conjecture or assumption without proof." In other words, someone's opinion.

Many years ago I made a study of harmonics. I was curious to know what happens to the wind in its journey from the blower to the time it came flowing out of an organ chamber as music. I studied all available books on the subject and soon found out that the definition given above was indeed correct. The explanations in most cases were just someone's opinion. Authors who certainly knew every phase of organ construction and operation lapsed into generalities when the subject of harmonics was attempted. Some authors made statements that contradicted other authors. In one book it seemed to me that the author contradicted himself.

There was one exception, Aristide Cavaillé-Coll, the famous French organ builder, who was also a great student of musical acoustics. He tried for facts as well as opinions. He invented apparatus to amplify and measure sound waves. It is reported he made wood stops, both open and stopped, with glass walls and had glass resonators made for reed pipes. Cavaillé-Coll played these stops with smoke to help him find the answers. Cavaillé-Coll was the first to explode the long held theory of the air forming an air-reed which vibrated directly in and out of the mouth of the pipe.

George Ashdown Audsley, of Bloomfield, N. J., was also a great student of organ lore. To gain authentic information for a book he went to France, where he worked with Cavaillé-Coll and obtained from him much information, part of which was facts as well as theory. Mr. Audsley was the author of "The Art of Organ Building" and "The Organ of the Twentieth Century." He included what he had learned from Cavaillé-Coll as well as his own deductions in his books.

To me Mr. Audsley's explanation of musical acoustics seemed to be the most logical. Many of his deductions are contained in this article, as well as other points of view well known to students of sound in organs.

I give this explanation to prevent a controversy with a reader who may be acquainted with some theory differing with the one described in the article here presented. Organ pipe talk can be very confusing to one who is not fully acquainted with the subject. Some parts are called by different names and in some instances different parts are designated by the same name. To make it clear to those not fully conversant with organ pipe talk, I give a few examples.

Harmonics — also called upper partials, partials, overtones and mutations.

Fundamental tone—also called prime tone, ground tone, unison tone. It is the loudest, most powerful and most assertive tone by which the pitch of the whole compound tone is judged. Pure organ tone is one having no audible harmonics. Compound organ tone is one created by combining the fundamental tone and all the harmonics used with it.

Flue pipes are more properly called labial pipes as referring to the lips.

Reed pipes are more properly called lingual pipes, referring to the tongue.

The *upper part of organ pipes* is called body, tubes and resonators.

In referring to the *number of sets of pipes* in an organ, they are designated as ranks of pipes, as an organ consisting of ten ranks. In referring to one set of pipes, it is designated as a stop, as a violin stop or a flute stop.

Half-length pipes are called stopped pipes if made of wood. If made of metal they are called covered pipes.

Mixtures and *compound stops,* which are pipes tuned and voiced to imitate harmonics and used in classic organs, are the same.

The *tube* which connects the pipe to

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"You may remember that last year, we had a series of silent movies at Occidental College. This was not Flicker Fingers; it was a silent movie festival. We played the scores on a concert organ, doing theater effects on the most rigid of concert instruments, a great Skinner."

ANOTHER place where Gaylord Carter is featured is the Los Angeles Sports Arena. "The Sports Arena is one of the places where an electronic organ has been installed to use before and during sporting events. The organ at the Dodger Stadium is a big feature of the action down there, and also at the new Aneheim Stadium where the Angels are. At the Sports Arena, I was privileged to play for the Blades, the Lakers, boxing events, track events and all sorts of sporting activities.

"There, you play, more or less, the kind of music which will heighten the action. People will come up to you and give you requests, and of course, all the kids want to hear the Batman theme and Beatle songs. During one of the intervals of a hockey game, we play selections from "My Fair Lady" and during the other one, numbers from "Sound of Music". All of this just to keep something going while the action is not taking place on the floor.

"Though they demolished the theaters, got rid of the theater organs, and maybe knocked the organ to the ropes a bit, it certainly has rebounded. There's always a spot for good music, and I'm very grateful that there's a revived interest in organ-playing. I believe this is due to several things.

"One, of course, is the invention and dissemination of the electronic instruments. So many people have organs in their homes now, so many youngsters are having the opportunity to learn to play the organ through free lessons which are given with the purchase of an organ, and later on, through study with a good teacher. When a person has an organ in his home, he's interested in organs being played in other places.

"Then, of course, the organ records which have been on the market, by distinguished musicians such as George Wright and many others, have given a great impetus to the interest in organ.

"Then, the organization, the ATOE, the Association of Theater Organ Enthusiasts. This is a group of people who have revived interest in organs, just as the ancient automobile societies have interested people in old, old automobiles.

"I've often wondered when I'm playing for a group of people from the ATOE, and there's all the enthusiasm; where were they when I was playing in the theater? There didn't seem to be anybody paying attention to the organ in those days. It was all taken for granted. The organ rose out of the pit, and we played a little organ solo. If the folks liked it, they gave you a big hand; if they didn't they sure *didn't* give you a big hand! There was never anybody you could really depend upon to be enthusiastic, *regardless* of what happened.

"But, it is enormously stimulating to me, having played the theater organs in the old days, and now seeing this revival of interest in the organ, in the silent movies and in the little presentations which we have.

"We recently went to Cincinnati with a Douglas Fairbanks picture, and 3,000 people turned out to see this presentation and hear the organ. They were enormously enthusiastic. It was a great night in the theater, and I'm sure I was having more fun than anybody there.

"One of the greatest experiences in the theater was to go to a place like the Paramount downtown, where there was the concert orchestra in the pit, the big stage show with the stage band, the organ playing a solo, and maybe a cartoon. There was a feeling that you were really *getting* something for your money.

"Now, you have that feeling today, too. But it's not quite the same. It may be that people spread it out a little bit. You go to the theater and see a great picture. You go to the Hollywood Bowl and hear a great orchestra. You go to a "Flicker Fingers" and hear a great theater organ."

IN CLOSING the interview, Don Wallace had this to say: "I'm quite sure, Gaylord, that probably we've whetted the interests of a lot of people to see and hear you play for the next "Flicker Fingers". You know, I think it's wonderful to be able to make a living, doing something you enjoy doing and having as much fun as obviously you have, from it."

"You're absolutely right, Don. I remember when I was graduated from Lincoln High School in Los Angeles out on North Broadway, the principal, Ethel Percy Andress said at the time, 'I hope that whatever it is which you do, which takes most of your time, will be the thing you enjoy most'. It certainly has been that in my case, and I'm very grateful."

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the chest is the foot in flue pipes. It is a boot in metal reed pipes. The extreme bottom which fits into the air hole in the wind chest is the toe on all stops.

In reed pipes the *shallot* (echalotte) is also called a reed. The vibrating part is the tongue.

Block refers to part of the mouth in a wood stop; its counterpart in a metal pipe is the languid. A block is also a metal part of a reed stop. It is at the top of the boot and holds up the resonator. The shallot is on its underside.*

Tongue is the vibrating brass strip in a reed pipe, also the hardwood piece that joins the upper lip to the front board in a 16′ octave of a wood open diapason.

*The parts listed are illustrated in the article, "How to Ruin a Theatre Organ," in the August, 1967, issue of this publication.

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A little understood element of a pipe organ is the harmonic structure of the pipe. Harmonics are present in some degree in every musical sound. In many sounds they are easily distinguishable, while in others they are not so plain and in some musical sounds they are so faint they are not audible to the human ear. The human singing voice, especially soprano, is the richest in harmonics or overtones. In highly resonant, metallic musical instruments such as cymbals, bells and triangles, they are very audible. Oriental gongs have a great number. Instruments with stretched strings played with a bow, violins, violas, cellos and bass viols are rich in harmonics. Brass instruments are high in harmonics.

Harmonics are the result of the natural law of sound which is a part of acoustics. They are musical acoustics. Harmonics reinforce the fundamental sound, influence the intensity and quality of a musical tone. They blend with the unison tone and with each other to make a single tone creating brilliance and richness.

This is the definition of harmonics as published in the *International Encyclopedia of Music and Musicians:* "Law of Harmonics—a sonorous body vibrates as a whole and at the same time vibrates in each of its several fractions as ½, ⅓, ¼, 1/5, 1/6, 1/7, etc." The harmonic intervals of ½, ⅓, ¼, 1/5, 1/6, 1/7, etc., always appear in the same regular and orderly succession. The first harmonic of ½ has nearly the same volume as the prime tone but from that point the volume diminishes as the harmonics ascend. Harmonics decrease in strength as they rise in pitch. The loudest instruments have the highest harmonics.

If there were no harmonics a pipe organ would be a pretty dismal sounding affair. There would only be the heavy, dull tones of the flute and diapason, for they are the only organ stops that have no audible harmonics. There would be no bright, colored stops that create diversified musical sounds and contrasting tone color.

To make it easier to understand this rather complicated subject, I am going to designate one pipe as a prime tone—8′ CC which vibrates 65.4 times per second. It is the first note on the manual of a 61-note rank of an 8′ stop. I am going to describe all the harmonics that would be used with that pipe in an organ.

The vibrations are International pitch, 523.3 C tuning fork.

Harmonic No. 1 — Eight full tones above the prime tone, the tone is C twice the vibrations of the prime tone, or 130.8. The fraction of the prime tone is ½, representing the tone of a 4′ open pipe and designated OCTAVE.

Harmonic No. 2 — Twelve full tones above the prime tone, the tone is G, three times the vibrations of the prime tone or 196.2. The fraction of the prime tone is ⅓, representing the tone of a 2⅔′ open pipe and designated 12TH or OCTAVE QUINT.

Harmonic No. 3 — Fifteen full tones above the prime tone, the tone is C1, four times the vibrations of the prime tone or 261.6. The fraction of the prime tone is ¼, representing the tone of a 2′ open pipe and designated 15TH or SUPER OCTAVE.

Harmonic No. 4 — Seventeen full tones above the prime tone, the tone is E1, five times the vibrations of the prime tone or 327. The fraction of the prime tone is 1/5, representing the tone of a 1-3/5′ open pipe and designated 17TH or TIERCE.

Harmonic No. 5—Nineteen full tones above the prime tone, the tone is G1, six times the vibrations of the prime tone or 392.4. The fraction of the prime tone is 1/6, representing the tone of a 1⅓′ open pipe and designated 19TH or LARIGOT.

Harmonic No. 6 — Between the 20th and 21st full tone above the prime tone, the tone is between A♯1 and B♭1, seven times the vibrations of the prime tone or 457.8. The fraction of the prime tone is 1/7, representing the tone of a 1-1/7′ open pipe and designated FLAT 21ST or SEPTIME. This partial is the only one that is not harmonious.

Harmonic No. 7 — Twenty-two full tones above the prime, the tone is C2, eight times the vibrations of the prime tone or 523.2. The fraction of the prime tone is ⅛, representing the tone of a 1′ open pipe and designated 22ND or OCTAVE 15TH.

This tabulation is for one pipe 8′ CC. Understand that the number of vibrations of the prime tone and each of the seven harmonics and the designating note and the length of the open pipe each harmonic represents will change with every note in every rank of pipes, 61, 73, 85 or 97 notes, less if the pitch is lower than 8′ CC and increase if the pipes are higher in pitch. The harmonics that are audible to the human ear go to the 31st and can be heard in some musical instruments such as orchestral bowed instruments and the human voice; however, the first seven as a rule are the only ones used in a pipe organ. Up to the sixth or seventh harmonics the quality is rich and sonorous, above the sixth and seventh the quality is harsh and screamy.

All of these harmonic upper partial tones do not appear in all ranks of harmonic pipes. A pipe can be made to speak with only one, two, three or the full range of harmonics. In flue pipes the length of the tube and whether it is stopped or open, the position, cut and arrangement of the mouth determines which harmonics are used. In reed pipes the mixture of the metal, the size, length and shape of the resonator is the determining factor, as well as the shape of the tongue and size and position of the hole in the shallot. The wind pressure is also a factor in both flue and reed pipes.

The wind from the blower does not go directly into the pipe like a tin whistle being blown by a kid. In flue or labial pipes the wind passes from the foot through a narrow slot formed by the cap and block in wood pipes and by the lower lip and languid in metal pipes. This stream of air or wind sheet strikes against the upper lip, where it divides. Some authorities say it moves back and forth across the upper lip like a fan; others say when the stream of air strikes the upper lip it forms into a vortex or whirling motion. Whichever way, it creates a suction which draws the air out of the bottom of the pipe, creating a partial vacuum. The air column in the pipe expands to fill this vacuum and this movement starts the air column into vibration, causing shocks, pulses and tremors within the pipe. This action takes place hundreds of times in a second. These pulsations are sound waves which produce the musical tone. The wind sheet striking the upper lip also creates a musical tone which must be the same frequency or vibrations per second as the prime tone of the pipe. The edge tone and the prime tone are thus coupled together. I have proven the edge tone by sawing off a pipe just above the upper lip so only the edge tone is sounding.

To prove these statements I suggest you hold your hand against the side of a 16′ wood pipe on a high pressure organ when it is sounding and you will feel the pulsations pounding against the pipe wall. To prove the vacuum principle of sound production, place a few bits of cotton inside the mouth of any large pipe and watch the cotton bits fly OUT of the pipe when it is sounded. Try blowing directly into a quart bottle; there will be no result, then blow across the top of the bottle and you will hear a musical tone. You have created a vacuum which set the air column in the bottle into vibration and created the musical sound. This demonstrates the principle used to produce tones in all flue or labial organ pipes.

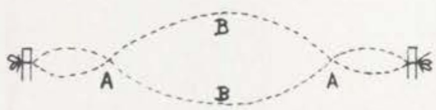

FIGURE 1. VIBRATING STRING, SHOWING NODES (A)

A simple experiment will illustrate a harmonic vibration or sound wave. Stretch about two feet of strong string between two pegs. Snap the string in the center (figure 1) at points A and A; there is no vibration. They are the nodes. The place of greatest movement, BB, is the anti-node. This is like a violin string producing the first partial. At the same time it also splits into fractions of ½, ⅓, ¼, 1/5, 1/6, 1/7, etc., of its length, producing a full series of harmonics.

Another experiment. Dismount an orchestra bell or metal marimba bar, lay it on strips of felt about one-quarter way from each end. Sprinkle fine sawdust or other small particles over the bar. Strike the bar repeatedly in the center with a rubber marimba hammer. The particles will start to dance and many will fall off but you will soon see many particles forming a line *across* the bar about one-third from each end. They will remain stationary, with no movement no matter how long you strike the bar. The particles are lying on the node where there is no vibration. This method is used by makers of bells, marimbas and xylophones to determine where to bore the

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mounting holes so they will not disrupt the tone quality.

Figure 2 represents an open flue pipe. It has one node slightly above the center and two sections of air and sounds the prime or fundamental tone. Figure 3 represents the same pipe. It has two nodes and three sections of air and sounds the first upper partial or octave. A are the nodes, B are the anti-nodes. The second harmonic has three nodes and four sections of air and sounds the 12th or octave quint. The number of nodes and sections of air continues to increase by one as they progress upward. All of the upper partials that have been allotted to any one pipe by the pipe designer and the voicer are moving up and down the barrel of the pipe all at the same time, each one vibrating at a different speed per second. They are also changing phase from condensation or compaction to rarification or thinning out, each time they reach an anti-node, each partial creating its own proper tone. They are all blending with the prime tone and with each other to create a harmonic structure with richness and brilliance. It is a natural law of sound, an acoustical phenomenon.

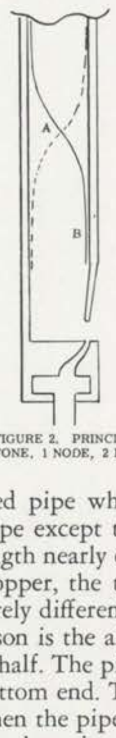

FIGURE 2. PRINCIPAL TONE, 1 NODE, 2 PARTS

In a stopped pipe which is identical to an open pipe except that it has been reduced in length nearly one-half and fitted with a stopper, the tonal quality or timbre is entirely different than the open pipe. The reason is the air column is reduced by one-half. The pipe is now open only at the bottom end. The stopper acts as a node. When the pipe speaks its fundamental tone there is no node formed in the air column as in an open pipe (Figure 2). The first harmonic octave (Figure 3) cannot be made as the sound wave is blocked at its center by the stopper. The second harmonic, the 12th or octave quint, is the first partial to speak in a stopped pipe. The third harmonic, the 15th or super octave, does not speak for the same reason the first or octave does not speak. The fourth harmonic, the 17th or tierce, speaks. The fifth harmonic, the 19th or larigot, speaks. The sixth harmonic, the flat 21st or septime, is not always used as it is not harmonious. The seventh harmonic, the 22nd or octave 15th, cannot be made as it is another octave not possible in a stopped pipe. The harmonics in a stopped pipe are the second, fourth and fifth, which produce an entirely different tone quality than the full range used in an open pipe.

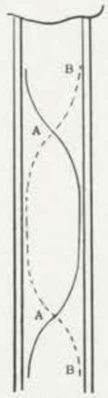

FIGURE 3. FIRST UPPER PARTIAL (OCTAVE), 2 NODES, 3 PARTS

Reed pipes all have harmonic development. The vibration of the tongue causes the column of air in the resonator to break up into vibrating segments. The length and thickness of the tongue supplies the proper pitch, the width and form of the tongue supplies the loudness and character of tone. The harmonics are created as already described for labial pipes. The reed and tongue produce a sound which has no true musical character but which has the same frequency as the prime tone produced in the resonator. The resonator changes this sound into a musical tone of definite pitch and timbre.

The reed or shallot is a brass tube slightly tapered, broader at the bottom and closed at the bottom end. It is made flat on one side which is the face. It is mounted in the block inside the boot and under the resonator. The properly sized, curved reed is mounted on the face and held in place by a wedge at the upper end. There is an opening in the face of the shallot. These openings vary in shape, proportion and position and create the harmonic build-up in the resonator. The curve of the tongue covers and uncovers the hole in the shallot by a rolling and unrolling motion. Figure 4-A is an open shallot running its entire length. This creates a tone rich in harmonics like the tubas, trumpets and post horns. B shows a partly opened or closed shallot. It is triangular in shape, extending about one-third way up the shallot. It creates a brilliant tone of the kinura, oboe, saxophone and clarinet. When used with a quarter-length resonator the tone is the vox humana. C is a "filled-in" shallot; it is the same size as the partly opened shallot but is located higher up the face so the tongue closes the orifice before it has completed its downward stroke, thus cutting off the harmonics of its extreme end. It is used for smooth-toned reed stops such as trombones, and French horns in classic organs. It is little used in theatre organs.

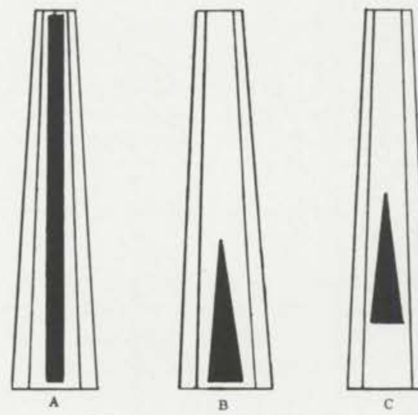

FIGURE 4. TYPES OF SHALLOT

In reed pipes the tuning is done by moving the tuning wire up or down on the tongue but many reed pipes have some means of regulating the tone quality, such as a slot with a changeable length on the side of the resonator near the top or bending a metal cover or shade as the clarinet or standard oboe, or turning the cap to open or close holes in the side of the resonator as a vox humana.

Reed stops are classified as open stops, such as the tuba, trumpet and posthorn; covered stops as an orchestral oboe. Partly covered stops as the clarinet, standard oboe or vox humana. To avoid very large reeds and tongues in reed pipes of the 32 and 16′ register a weight, usually a brass button, is attached to the lower end of the tongues. This is called a "loaded tongue."

(Dan Barton's treatise on harmonics will be continued in the next issue.)

How to Play Cinema Organ

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press upon organists the importance of and if that is intermittent and unsteady, the music has no vitality, it is sick, ailing and feeble, there is no life in it, it is of no use, and has no message to convey.

Classical Music. We assume that the student has already acquired a good general technique, and if his training in organ playing has been upon recognized and standard lines, he will know how to treat such music. The organist who is also an artist, will never miss a suitable opportunity for introducing music of a superior nature; at the same time, if he is wise, he will not overdo it.

Intermezzo. By the term "intermezzo,"

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