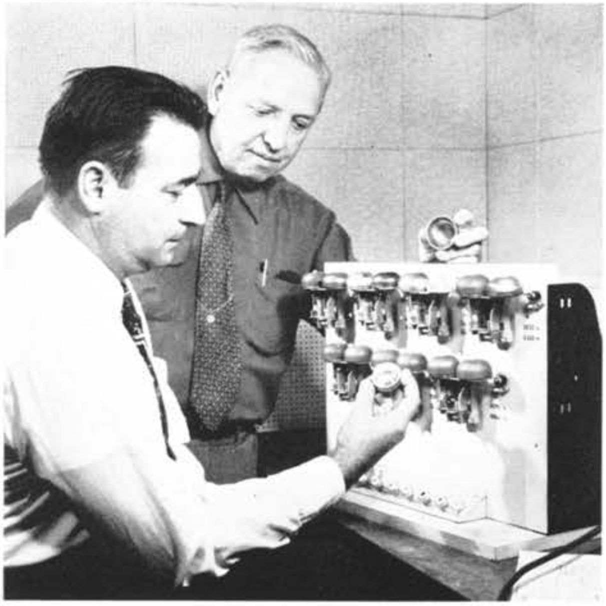

# *Distinctive Ringing Signals for the 500 Set*

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**In a large business office, or in other situations where two or more telephones are in the same room, it is a great convenience if each telephone has its own distinctive ringing signal. In this way the user can recognize his telephone even when he is away from his desk and when other telephones are ringing at the same time. By the use of different metals of varying thicknesses, Laboratories engineers have developed a series of gongs to provide up to seven distinct ringing signals.**

Gongs and bells have been used for centuries to attract attention and to call people together. Their continued popularity is largely due to their inherent qualities as sound generators and to the fact that they can be very distinctive. Distinctiveness involves several factors. One of these is pitch – an auditory sensation related to frequency, sound pressure, and wave form – whose value is established by comparison with a simple tone. Although pitch is related to the fundamental frequency of the sounding device, the two are not necessarily identical. Fundamental frequency is related to the dimensions of the gong, and in general the larger gongs have lower fundamental frequencies. Large gongs are also efficient radiators of sound.

Another distinctive feature of gongs and bells is that all such devices radiate a complex sound that includes many overtones, which gives each its own individual tone quality. Besides these factors of pitch and quality, gongs and bells can also acquire distinctiveness from the code or sequence with which the clapper is allowed to strike and by virtue of the directional properties of the sound that is being radiated.

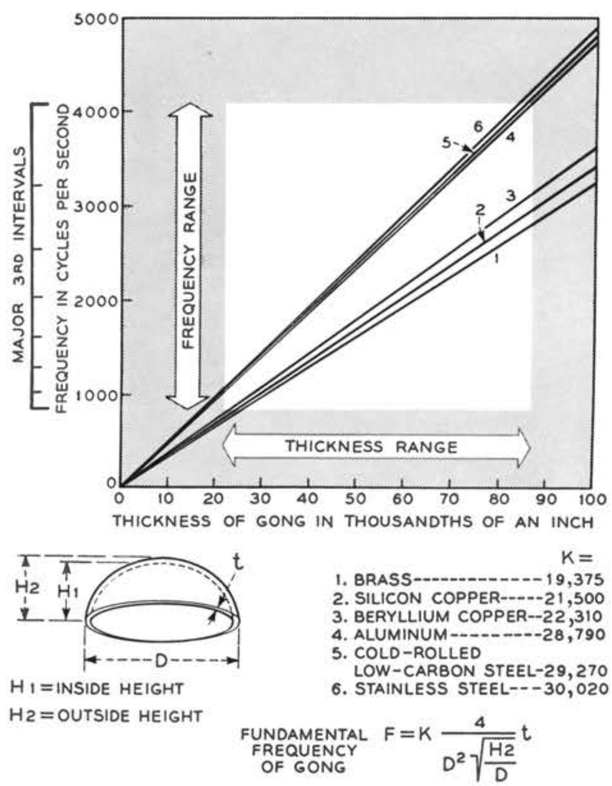
Gongs were therefore a natural selection for producing audible signals to summon users to the telephone. Usually, two gongs of different pitch are incorporated into a telephone ringer and are sounded by a vibrating clapper driven by an electromagnet. Such ringers perform their function of providing an attention-attracting and pleasant sound, but with uniform installation of ringers it is sometimes impossible to distinguish the signal of a particular telephone from others in the immediate vicinity. Since increasingly large numbers of telephones are now used at some locations, Bell Laboratories has been engaged in developing a series of gongs, so that several different ringers can be installed in the various telephones in a room to permit each user to recognize his own signal.

Of the many ways of achieving a distinctive ringing signal, gongs of different pitch offered the most attractive possibilities for this particular application. The metal of a gong can be cut in various ways to alter the sound, and snubber attachments can be used, but these methods affect ringer performance adversely. Resonating the fundamental frequency of a gong suggests another possibility, but this could provide at best only two or three distinctive tones.

For gongs used in the 500-type telephone set ringer,* the distinctive pitch is largely determined by the fundamental frequency of the gong. Superimposed upon the fundamental are many overtone frequencies, but, unlike the simpler sound spectra of some musical instruments, these overtones are not harmonically related. That is, their frequencies are not whole multiples of the fundamental. For example, the first overtone is about 2.6 times the fundamental and the second is about 4.7. It is this order of component relationships that gives these gongs their characteristic tone quality.

Despite this complexity of the sound, however, distinctiveness in these gongs largely results from the magnitude of the interval between the fundamental frequency of one gong and the fundamental frequency of another. In other words, if the fundamental frequencies of two gongs should differ in a ratio as much as 2:1, the two will be generally distinguishable, but if the frequency ratio is quite small, say 9:8, we might have difficulty telling one from the other. Precise information on this point was necessary before determining the

* RECORD, *October*, 1951, *page* 471.




$$F = K \frac{4}{D^2\sqrt{\frac{H2}{D}}}\, t$$

*Fig. 2 — Graphs of six possible metals for distinctive gongs, relating thickness to fundamental frequency according to the design formula.*

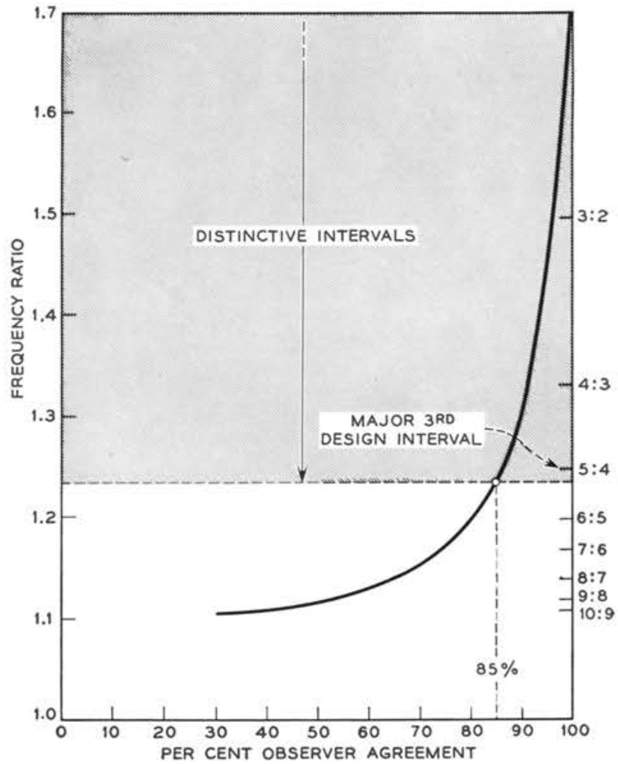



*Fig. 1 — Frequency interval between two gongs versus per cent agreement on distinctiveness among twenty observers; 85 per cent agreement determined design interval of a musical third.*

pitch interval for a specific design of gongs, which in turn determines how many different gongs could be supplied within a frequency range practicable in a telephone set (about 800 to 4,000 cycles per second).

To determine a distinctive pitch interval, listening tests were conducted using ringers covering a range of fundamental frequencies from 1240 to 3,570 cycles per second. Two gongs were used on each ringer. In some cases these two gongs were of the same fundamental frequency; in others the two were of different fundamental frequencies as in the 300- and 500-type telephone sets. In the latter two-gong combinations, the pitch frequency is closely that of the lower of the fundamental frequencies.

Twenty observers with normal hearing participated in the listening tests, and the results were scored according to observer opinion as to whether ringers, compared two at a time, were or were not distinctive. Each ringer of the series was compared with every other ringer. It was decided that two ringers were sufficiently distinct from each other if 85 per cent of the listeners could distinguish between them. Figure 1 shows the frequency

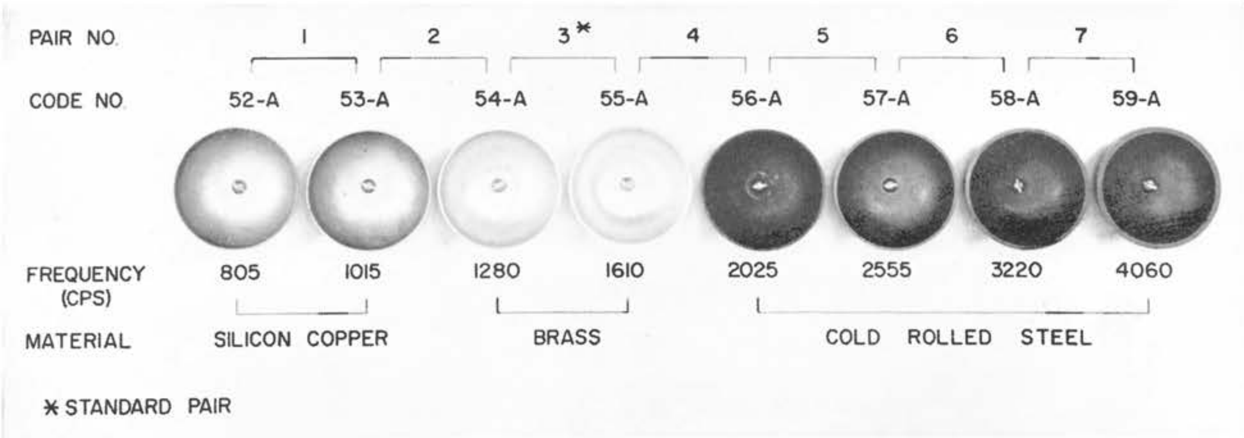



*Fig. 3 — The eight distinctive gongs grouped into seven ringer pairs. Brass gongs are in 500 set ringer.*

interval between two ringers, computed from the number of distinctive tones, versus the percentage of observers in agreement on the number of such tones. The distinctive interval was computed from the relationship $A = 2.88^{1/(n-1)}$ where A is the interval, n the number of distinctive tones, and 2.88 is the ratio of the extremes of the frequency range used in the tests.

On this basis, it was found that two ringers are distinctive if their fundamental frequencies stand in a minimum ratio of 1.24, or about 5:4. The 5:4 ratio closely approximates the interval which in musical terminology is referred to as a major third — for example, the interval included by the notes C and E on a piano keyboard.

Ten experimental ringers spaced a musical third apart were then tested in the presence of various types of noise. Each of these ringers was equipped with two gongs of nearly the same fundamental frequency, ranging from 425 to 3,530 cycles per second. Twenty observers with normal hearing and sixteen with deficient hearing participated. Distinctiveness for these tests was based on the observer's ability to distinguish a given ringer 75 per cent of the time. Results showed that for general-type noise (simulated room noise and other common noises) up to a 70-lb level, all ten test ringers were judged to be distinctive by 85 per cent of the observers in each group. Similar results were obtained for flat-type noise (wide-frequency noise like that from escaping air, running water, and vacuum cleaners), except that at the highest noise level of 70 db, a maximum of nine ringers were judged distinctive by the participants with normal hearing. Those with deficient hearing were still able to distinguish all ten ringers.

On the basis of these studies, a series of distinctive-tone gongs with the musical third relationship was designed for the 500 set ringer. Since the gongs used are of circular cross-section, and since all must be interchangeable on the ringer, a design requirement was that all gongs have the same outside diameter and inside height (see drawing of gong in Figure 2). Therefore, the only variables for obtaining different frequencies were the metal used in fabricating the gongs and the thickness of this metal.

All of the above factors are included in a formula used to determine the fundamental frequencies of gongs. This formula, shown in Figure 2, is a modification of the classical Rayleigh formula for the fundamental frequency of a cylindrical shell, and it includes a constant K which is character-

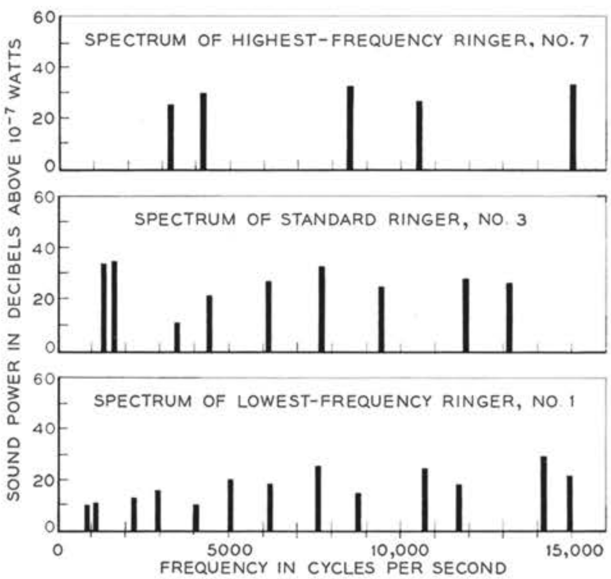



*Fig. 4 — Sound spectra of the lowest, standard and highest frequency distinctive ringers.*

istic of the metal. The dimension $H_2$ in the formula refers to the outside height of the gong, rather than the inside height used as a design requirement.

In practice, the range of available thicknesses is limited. If the gong is too thin, it is easily deformed, and if it is too thick, it is difficult to fabricate and will not fit over the resonators incorporated into standard ringers. The range of thickness used is from 0.022 inch to 0.087 inch, a ratio of about 4 to 1, which is insufficient to cover the desired frequency range. It was therefore necessary to use more than one metal for the gongs.

Many metals and metal alloys can be considered, and six are graphed in Figure 2. This illustration shows how types of metal and thickness of metal are related to fundamental frequency by the design formula. It also shows how metals must be chosen so that an optimum number of gongs of the musical third interval may be accommodated within any given range of frequencies.

Among other considerations governing the choice of metals, the temper of the metal must be adaptable to the forming process used in fabricating the gongs. Further, the metal must permit a satisfactory "decay rate" of sound output at a given frequency. (The reason for this is that to the human ear, some gong sounds become unpleasant if they persist for too long a time. A high-frequency gong sound should decay or damp out fairly rapidly, but the ear will tolerate a longer persistence of the lower frequencies.) Finally, the metal must be suitable for fabricating a gong that will not have objectionable "beat frequencies" – unpleasant low-frequency pulsations resulting from strains in the material.

Of the six metals and alloys, some had to be ruled out for one or more of the above reasons. Stainless steel gongs, for example, exhibited bad beat frequencies caused by the strains introduced into the metal in the forming process. These strains could not be satisfactorily reduced by annealing. Brass could not be used for high-frequency gongs because of the large thicknesses involved, and aluminum was unsuitable because of unacceptable decay rates.

By the use of silicon-copper, cold rolled steel, and brass, a series of eight distinctive-tone gongs was developed. These are shown in Figure 3, along with their fundamental frequencies. A silicon copper was chosen for the two low-frequency gongs, and cold rolled steel was chosen for the four higher-frequency units. The two standard brass C-type ringer gongs were retained for the intermediate frequencies. These materials have tempers suitable for forming, and annealing reduces beat frequencies to an unobjectionable rate. From Figure 3, it can be seen that by proper combination of these eight gongs into pairs, seven distinctive ringer combinations are achieved, of which one (number 3) is the standard ringer pair used in most 500 sets. Other combinations may be used in special applications.

These gongs have a nominal outside diameter

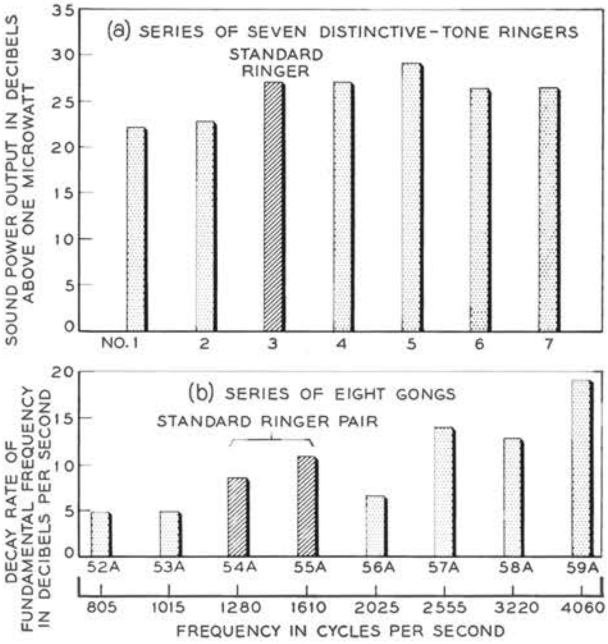



*Fig. 5 — (a) Sound-power output in 500 set of the seven distinctive ringers; (b) decay rates of the eight gongs incorporated into the ringers.*

of 1.875 inches and inside height of 0.850 inch. They are formed by cold pressing with a punch and die, and the strains introduced in this cold-working process are subsequently relieved by annealing. The silicon copper and brass gongs are corrosion resistant, but the cold rolled steel gongs are given a light coating of a phosphate rust preventive which does not appreciably affect gong frequency or decay rate.

When installed in telephone sets, the seven ringer combinations yield the sound-power outputs shown in Figure 5(a). The outputs range from 22 db to 29 db above one microwatt. The decay rates for the fundamental frequencies of the individual gongs are shown in Figure 5(b), where it is noticed that the higher-frequency units generally have the greater decay rate (less persistence). This is a desirable characteristic for pleasantness of

*Fig. 6 — The author determining sound spectrum of ringer with sound integrator and frequency analyzer.*

sound and is typical of musical instruments in general. Figure 4 shows sound spectra for the lowest-, standard-, and highest-frequency ringer combinations (numbers 1, 3 and 7). The measurements for such graphs were made with the Sound Integrator* and Frequency Analyzer (Figure 6), and with a Level Recorder and associated equipment. The spectrum analyses illustrate the inharmonic relationships of the overtones and the fact that many more overtones are present in the output of the lower-frequency units.

The seven ringer combinations designed in this project provide the desired degree of distinctiveness, but for maximum effectiveness in an actual installation, one must take account of several other factors — the acoustic nature of the room or office in which the 500 sets are placed, the number of telephones in a given area, and the spacing and distribution of the positions. In general, it is desirable to use as wide a frequency separation as conveniently possible for a given number of telephones. However, in any situation, the standard ringer combination is used as widely as feasible.

In the initial tests, observers with deficient hearing were taken into account in determining the effectiveness of the distinctive pitch interval for experimental ringers, but the question remained as to the degree of effectiveness in this circumstance of the actual designs as installed in 500 sets. Accordingly, additional tests were conducted with a number of such observers, two of whom were accustomed to wearing hearing aids. As earlier, the tests were conducted under quiet conditions and in the presence of typical room noise and wide-frequency band noise. These tests indicated that, in general, hard-of-hearing users will find the three ringers of intermediate frequency (numbers 3, 4 and 5) more effective, with number 4 most effective for general room noise. In the presence of considerable high-frequency noise, however, ringer numbers 2 and 3 are to be preferred; and in situations where the hard-of-hearing user is frequently at some distance from his telephone (say 10 to 20 feet), the tests indicate that ringer number 5 will sound louder than others in the series.

These distinctive-tone gongs for the 500 set illustrate the care and close attention that must be paid to designs for use by the telephone customer. In all cases, the convenience and utility to the many users are of major importance along with the strictly technical and scientific aspects of the design. These distinctive ringers should be very helpful to business office procedure.

* Record, *September,* 1954, *page* 331.

**THE AUTHOR**

R. T. Jenkins was born in Exeter, Devon, England, and he received the B.S. degree in 1917 and E.E. degree in 1920 from Cooper Union. He joined the Western Electric Company Engineering Department in 1916, where his early work was concerned with telephone transmitter and receiver testing methods and telephone transmission problems. After incorporation of Bell Telephone Laboratories, Mr. Jenkins concentrated on general acoustical measurements in the Research Department, and on the development and calibration of telephone instruments. From 1942-1946 he engaged in work for the N.D.R.C. and the Navy Department. Since 1946, he has specialized in the development of station signals and acoustical methods of measurement of station apparatus components, and at present he is engaged in the field of new coin-telephone exploratory development. Mr. Jenkins is a member of the American Institute of Physics and a charter member of the Acoustical Society of America.