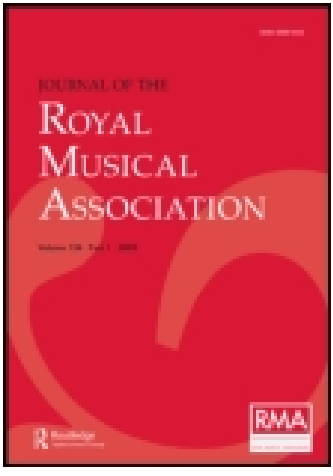

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DECEMBER 10, 1901.

T. L. SOUTHGATE, ESQ.,

IN THE CHAIR.

BELLS AND BELL TONES.

BY W. W. STARMER, A.R.A.M.

I have chosen this subject for consideration to-night because there is much to say from the musician's point of view, and because comparatively nothing of importance has been written on the harmonics of bells (I prefer to call them bell tones) and the way they should be tuned so as to produce the purest musical sound. I do not wish to pose as an expert on the manufacture of bells, but would prefer that my remarks, other than the statements of historic fact, should be looked upon as observations of a musician on the various characteristics and peculiarities of bells, from which I shall strive to lay down certain conditions with reference to the perfecting of the tone of bells, rather than the consideration as to how such results are to be obtained. This is undoubtedly the business of the bell-founder, and for the present must be left with him. For the sake of completeness, I shall give as concisely as possible a history of church bells, with some explanation of their construction, before dealing with the matter of bell tones.

First of all, as to the definition and derivation of the word "bell." We may safely say that it is derived from the Saxon *bellan*, to bellow. Dr. Johnson, in his dictionary published in 1755, defines a bell as "a vessel or hollow body of cast metal, formed to make a noise by the action of a clapper." In another work, printed about the same time, a bell is described as "a popular machine, ranked by musicians among the instruments of percussion, made of a compound metal of copper and tin, hung in steeples of churches and in houses." We might more correctly define a bell as a hollow body of metal, ranked among the musical

instruments of percussion, made of an alloy of copper and tin, and so formed as to emit a clear ringing sound when struck.

With reference to the bells mentioned in the Bible, little need be said, as there is nothing to show that they were anything but ornaments.

Carl Engel, in his catalogue of musical instruments in the South Kensington Museum, tells us that the Jews have at the present day in their synagogues, small bells fastened to the rolls of the Law containing the Pentateuch, a kind of ornamentation supposed to have been in use from time immemorial.

It would seem that the bell originated in China, although direct evidence is not forthcoming, which is surprising, considering that bells have been in use there for nearly four-thousand years.

Small bells have been found with early mummies at Thebes, and it was the descendants of these mummies who colonized ancient Greece.

In Assyria, bells were extensively employed. Mr. Layard discovered eighty small bronze bells, having iron tongues, at Nineveh in the palace of Nimroud, thus proving that such things must have been common.

In the wars between Greece and Rome they were much used.

The oldest bells yet discovered are not castings, but plates of metal bent into shape, and riveted or brazed together where the edges meet. Such were used by the Assyrians and ancient Chinese.

It is curious to note that previous to 1840 there was but little antiquarian research in connection with the origin of the bell. However, there is not the slightest doubt that bells, as we now know them, were invented by the Christian Church, though not at the earliest stage of its existence, for then, in consequence of persecution, no loud summons was possible as a signal for assembling together. On account of this research being comparatively recent, the information respecting the invention is so indefinite that the conclusions arrived at are by inference from a few recorded facts.

Paulinus, Bishop of Nola in Campania (fifth century), is credited with the invention. There is not the slightest evidence, however, to prove this to be the case.

In 750, the building of churches and founding of bells were much encouraged by a decree which provided that a Thane's rank might be obtained by a Saxon churl or franklin, if he were rich enough to possess 500 acres of land, and had a church with a *bell tower* on his estate.

St. Dunstan (tenth century) is credited with casting a bell which for ages hung in Canterbury Cathedral.

I must pass over the curious custom of baptising bells, and also their peculiar uses in convents and monasteries, and will here quote a passage from Dr. Stainer's well-known work on the music of the Bible, which is a reasonable conjecture as to the origin and development of the bell:—

"Plates of metal were attached to the caparisons of horses, so as to produce a jingling noise, and if these plates had a circular indentation they would be little cymbals; and if the indentation should be made deeper, and the rim gradually bent into a circular outline, a little bell is the result. The gradual change of metal plates into bells is interesting and important. The indentation of cymbals would be found to add to their vibrating power and sonority, and as this indentation became exaggerated, nothing would be more probable than that they should eventually be formed into half globes. This form is actually to be found in Roman and Greek sculpture. Then again, in course of time, these hemispherical bells would be found to be shrill and noisy in tone. Then again would naturally follow the experiments, as made in Europe, of moulding the rim slightly out-turned, and thickening the metal. Here at last we have a real bell, with the so-called sound-bow or thick lip."

The first English bell-founder was Roger de Ropeforde, of Paignton, employed in 1284 to cast four bells for Exeter Cathedral.

In many cases the ages of our earliest bells cannot be definitely determined, for they have no marks or signs as to the date when, or the place where, they were cast. The absence of dates on these bells is a great mystery. The oldest *dated* bell in Europe, as far as I know, is that of the Cathedral of Siena, which bears the date 1159. The oldest bell in England appears to be that lately removed from Lauhydrock Church, Cornwall, on which is the inscription: "The gift of Athelstan for his soul." The earliest dated bell in England is at St. Chad's Church, Claughton, Lancashire, 1296.

We possess, comparatively speaking, very few old bells, which may be accounted for thus: first, by the introduction of change-ringing in the seventeenth century, which caused old bells to be re-cast, so as to produce the notes of the major scale in their proper order; secondly, by the havoc and destruction made upon them at the time of the Reformation. Henry VIII., in the general confiscation of church property, looked upon bells as so much metal that could be realized, consequently many were sold as old metal. In the eighteenth century, it was a common way of raising money to pay for the restoration of the church, to petition the Bishop to grant a faculty empowering the parishioners to dispose of the bells, which were declared to be unnecessary or cracked, and therefore useless.

Although the oldest bells are not dated, they have upon them interesting marks and inscriptions, and for one moment I will call your attention to these :—

EARLIEST PERIOD.

Pre-Reformation—	
Dedicated to God - - -	Te Deum laudamus.
„ to Saints - - -	Sancta Catarina.
„ Invocation to Saints -	Sancta Catarina ora pro nobis.

LATER PERIOD.

Religious and Royal - -	Fear God Honour the King.
Proverbial - - - -	Music is medicine to the mind.
Egotistical - - - -	I mean to make it understood that though I'm little I am good.
In praise of the donor of bell	Ring boyes and keep awake, For Mr. William Henchman's sake.
Bell-founder's glorification -	Badgworth ringers they were mad, Because Rigbe made me bad, But Abel Rudhall you may see Hath made me better than Rigbe.

During the eighteenth century these inscriptions in many instances were absurd and ridiculous. I will mention three as specimens :—

(1.) The King, Pitt and Quebec for ever. Frampton Cottrell.

(2.) I dance and sing for George our King,
Little and loud, short and proud,
Despise not the day of small things. Wilton.

(3.) Prosperity to the Established Church
and no encouragement to enthusiasm.
St. Mary Whittlesea.

If time would permit I should most certainly have something to say about bell-ringing, the curious and interesting customs connected with bells, and particulars of the most famous bells of the world, but as I am anxious to give the greatest amount of attention to the part of the subject which I feel confident is of the greatest interest to musicians, I must pass these over reluctantly.

It will not be out of place at this point to consider a few interesting facts as to how bells are made. First of all, the metal is nothing more or less than a species of bronze. It is an alloy—that is to say, a compound of two or more metals. It is curious that in bronze, density and hardness are increased by combining softer and lighter metals. Copper becomes more sonorous by combination with another metal. Authorities differ as to the proportions of copper and tin to make the best bell-metal. In the reign of Henry III., two parts of copper to one of tin were used. At the present day copper and tin in the proportion of 13 to 4 are used, and there is no doubt that small quantities of other metals found in old bell-metal are most likely impurities in the metals used to form the alloy. The bronze used for the English coinage consists of 95 parts of copper, 4 of tin, 1 of zinc; thus you see that bell-metal is more valuable than the bronze our coins are made of; indeed, the first bronze coins were made in France out of old bells melted down. There is a very erroneous opinion that silver improves the tone of bells. This is not so, and if used to any great extent would injure the tone. It was the custom, when bells were frequently cast in the churchyard, to throw a few coins into the furnace, and it may have been on account of this that such an idea was created.

Bells have been made of steel, but they are very unsatisfactory. They have also been made of glass, and successfully with regard to tone, but, this substance being very brittle, it is unable to withstand the continued use of the clapper.

The quality of tone produced by a bell depends not only upon the composition of the metal, but upon the shape, height, width, and thickness proportions. The smaller the bell the higher the pitch. Among German bell-founders the rules for proportions, taking thickness of sound bow as the unit, are: thickness of sound bow, 1; diameter of mouth, 15; diameter of shoulder, $7\frac{1}{2}$; height, 12.

Now the process of making bells, although difficult of intelligible explanation without the aid of models, is something like the following: First, the inner mould, or core, is made, and consists of brickwork (or an equivalent) covered with loam, and moulded to the shape of the inside of the bell by means of what is called a sweep or crook. Next, the cope or cover, which forms the outside of the bell, is made, and consists of an iron case lined with loam, moulded to the shape of the outside of the bell. Both core and cope are baked hard in an oven specially built for the purpose. A hole is then dug in the sand, into which the core is laid, the cope is placed over it, and the hole is then filled in and the sand rammed down tightly. The core and cope when thus united are called the "mould" for the bell. Everything being

ready, the furnace is tapped, and the molten metal as it pours out falls into a large iron ladle lined inside with sand. This ladle, after receiving the metal, is carried by a crane to the mould, and the metal is then poured out from the ladle into the hole in the top of the crown and fills the space between core and cope. When cool, the bell is taken out and carried into the finishing department, where it is tuned.

This used to be done by chipping away the inside of the bell, or the edge of the lip—an exceedingly clumsy method indeed. Now, however, with our improved machinery, it is done much more satisfactorily by a sort of vertical lathe. The bell is inverted, and gripped at different points by powerful vices, to keep it perfectly firm. The centre is then plumbed, and steel cutters revolve, paring *out* the metal from the inside of the bell for flattening, and paring *off* the edge of the bell for sharpening. By this means, bells can be very accurately tuned. In casting, bells are best left sharp, for flattening injures the tone much less than sharpening. A bell may readily be flattened one-eighth of a tone, or even more, but it cannot be sharpened so much; indeed, any sharpening is to be deprecated, and if at all possible should be avoided.

When a peal of bells is cast in tune, *i.e.*, needing no adjusting in the tuning machine, it is called a "maiden" peal. This used to be a rare occurrence, and only a chance, but now, with our improved appliances, and if care be taken, there is no reason why bells should not be cast so that very little tuning is required.

A less quantity of metal than is due to the calibre of the bell, produces a thin and unmusical tone. One reason why some old bells are superior to modern ones, is no doubt due to the fact that a greater weight of metal was used for the same note than is thought necessary now, on the ground of economy.

I have mentioned in general terms the means adopted in most foundries for the tuning of bells. I have had an opportunity of seeing this done in a number of foundries, and must say, that from a musical point of view, it has been done up to the present in a very unsatisfactory manner. I think that we, as musicians, have never taken the interest in bells we should have. Perhaps this may be due to the fact of their not being considered musical instruments. Unfortunately, many of them are far from being musical, but there is a remedy for this, and we have now amongst us those who can get rid of nearly all the dissonant qualities to be found in the majority of existing church bells.

Some four or five years ago, one of our most eminent musicians had to pass judgment on a peal of bells. I had some conversation with him on the subject, as he knew I was

very keen about such things. The opinion he expressed was favourable so far as it went, but I well remember the last sentence, which ran thus: "They are less out of tune than most of the bells I have examined." It was this that stirred up my enthusiasm, and this alone which is responsible for the following results of my endeavours to find out why bells should be possessed of such characteristics.

Let me make it quite plain to you that I do not wish to claim any originality for the views I am about to express with reference to bell tones. They are the same as those of any other musician who will take the trouble to analyse the tone of bells, and learn from them their differences and peculiarities. As far as I know, they have never before been treated in this collective form, or from the same standpoint, and that is why I am anxious to bring these considerations before musicians, in order to stimulate the interest they should have in seeing the best musical possibilities attained.

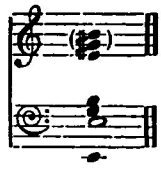
We must understand from the first that "tone" and "tune" are very different things. Good tone does not necessarily mean that a bell is in tune with itself or with others, and a bell may easily be in tune in the strictest meaning of the term, and yet of indifferent tone. Of course, the sound of a bell is a compound tone, which presents prominently to the ear five (and in many instances more) notes.

I take for granted that everyone present is well acquainted with the harmonic series of a vibrating string. I mention this because there is one great difference to be noted in the case of bells, and that is the presence of the minor third, which is not unfrequently one of the loudest tones, next to the fundamental, in the bell. Why it should be so I cannot say, and I have not yet found anyone who could give a reason for this. I put the question to one of the best known professors of acoustics, and his reply was: "We know something of the laws which govern the vibrations of a metal plate; bend it and we know less; out-turn the rim and we know still less."

I will now explain the terms "strike note," "tap note" or "fundamental," "hum note," and "nominal," as I shall have to use these frequently.

When a bell is properly struck, the first note which prominently attracts the attention of the ear is what is known as the strike note, tap note, or fundamental, this is what we call *the* note of the bell. The low sound heard after the strike note has lost its intensity is called the hum note. The octave above the strike note is called the nominal. There are also present a minor third and perfect fifth in the first octave, and a major third and perfect fifth in the second octave.

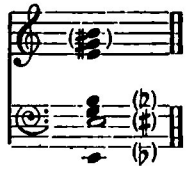
To make this quite understood, here is a diagram of the tones of the famous Erfurt bell:—



Now in order to arrive at a clear idea of what a good bell should be, I will take three well-known specimens, the Bell of Erfurt, the Tenor of Lavenham, and the Tenor of Beverley Minster. The "tenor" is, of course, the largest bell of a peal.

Bell of Erfurt.

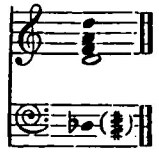
Date, 1497; diameter, 8 feet $5\frac{3}{4}$ inches; weight, 13 tons 15 cwts.; note, E.



I would here point out that the notes mentioned in Helmholtz's treatise, and which he gives on the authority of the organist Gleitz, are not quite correct. He gives the first third as G sharp, whereas it should be G natural. This is a very important point to notice.

The Lavenham Bell.

Founded by Miles Graye; date, 1625; diameter, 4 feet $4\frac{1}{4}$ inches; weight, about 24 cwts.; note, D.



The last bell I will mention is—

THE BEVERLEY BELL.

Founded by Taylor; date, 1901; diameter, 5 feet 1 inch; weight, 41½ cwts.; note, C.

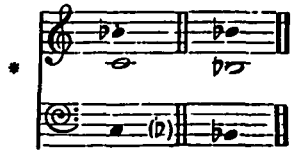
I could give you many other instances, but it would be merely duplicating the evidence, and this is quite unnecessary, as we should arrive at exactly the same conclusions. And what are these conclusions? (1.) That the hum-note should be a perfect octave below the strike note; (2.) That the nominal should be a perfect octave above the strike-note; (3.) That the third above the strike-note is always a minor third, and the fifth perfect; (4.) That all these notes should be in perfect tune with the strike note, and, of course, with themselves. Above the nominal, the major third and the perfect fifth can be heard in bells of considerable size; in smaller bells they are so weak as not to be worthy of consideration.

Now, turning to the greater number of our own bells, how do they agree with these conditions? In very few instances is the hum-note anywhere near the note it should be. Generally it is a sixth or seventh, and in rare instances a ninth below the strike-note. The nominal is somewhere about an eighth or ninth above the strike-note, and the other tones of the bell generally about as much away from the notes they should be as these. The third is in many instances accurate, but always a minor third.

Here are a few examples of bells supposed to be good :—

ST. SAVIOUR'S, SOUTHWARK.

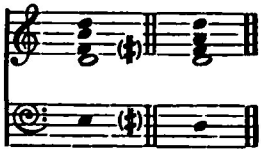
Founded by Samuel Knight; date, 1734; diameter, 5 feet 6 inches; weight, 52 cwts.; note, B flat.



* The first group of notes in each diagram represents the actual notes of the bell; the second group shows the notes as they should be. A ♯ or ♭ placed after a note indicates that the note is slightly inclined in that direction.

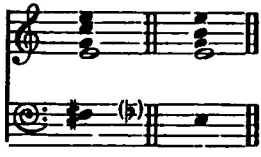
PAINSWICK BELLS (TENOR).

Founded by Rudhall; date, 1731; diameter, 4 feet 5 inches; weight, 25¼ cwts.; note, D.



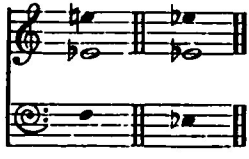
ELEVENTH BELL.

Founded by Rudhall; date, 1731; diameter, 4 feet; weight, 18 cwts.; note, E.



TENOR, ST. ANDREW'S, WELLS STREET.

Founded by Lewis; weight, 21 cwts.; note, E flat.



I am sure you will readily admit that bells containing such tones as these cannot be as satisfactory, musically, as if they conformed to the conditions found to exist in the good bells I have mentioned. I maintain that a bell must be in tune with itself before it can possibly be in tune with others. The reason that these tones in English bells are so wide of the mark is no doubt due to several things, but principally to the alterations of proportions that have been considered necessary, so that bells may be hung for change-ringing. The gradation between the large and small bells of a peal has always been a serious difficulty to bell-founders—the difficulty of preventing the small bells of a peal being swamped by the larger ones. Of course, both shape and thickness enter largely into this matter. It is so different on the Continent, where most bells are hung "dead," as it is

termed, that is, of course, fixed so as not to be swung. Under such conditions, when the design of one bell has been determined, that does for all relatively. The old method of tuning bells discards all other notes but one, and this no doubt is due to the fact that tuners do not know how to tune the other tones of the bell.

On the Continent, the best bells have their fundamental and hum-notes in tune. This is one great difference between the tuning of English and foreign bells, the English in most instances only having their nominals in tune with each other, and the strike notes more or less so. There is no doubt that the first note to be tuned is the strike-note, which must be freed from any interference whatever from other tones. Until this has been accomplished, nothing satisfactory with regard to the other notes can be done.

Next in importance come the hum-note and the nominal. When these are tuned in perfect octaves, as they should be, on account of the reinforcement they give to the strike-note, *i.e.*, the note of the bell, thus more definitely asserting it, the other tones can be easily managed.

As I said before, the higher tones are less important, and for the simple reason that, excepting in the case of large bells, they cannot be appreciated. The fact of the hum-notes being in tune with the strike-notes very greatly improves a peal of bells, and particularly of small bells. It is curious that this should be so, but they are extremely prominent, and the effect is very pleasing to the listener. One hears a succession of octaves instead of single notes.

I wish more had been written with reference to the harmonics of bells, but there are two authors who deserve mention here. Canon Simpson experimented, and wrote respecting the results of his experiments, which had the effect of turning the attention of Messrs. Taylor, the well-known founders of Loughborough, to this matter. At the present moment, as far as I am aware, no other founders in this country can produce a bell fulfilling the conditions I have laid down, in fact, I do not think that any other bell-founder has the necessary machinery to do this.

Canon Simpson in his articles devoted his attention principally to the nominals, and the desirability of making them true octaves with the fundamentals. He did not consider the hum-note much, and does not appear to have made any successful experiments with the tuning of this note.

For those who are interested in the subject, I would recommend them to read his articles which appeared in the *Pall Mall Magazine*, 1895-96, and which have been reprinted by Messrs. Skeffington.

The other writer is Mr. Thomas C. Lewis, of organ-building fame, who, in his brochure on the "Modern Development of

Unmusical Tone," devotes one chapter to bells. The views Mr. Lewis takes of the notes contained in a bell do not quite agree with those I have already expressed. I quote him fully, as, to be quite fair, it would be difficult to do otherwise. He says:—

"People who are ignorant of, or are unable to recognise what should be the proper bell nature shown in tone, are similarly circumstanced to those who are no judges of organ tone, and who, with preconceived notions, rail against the mixtures, and what they are pleased to call in their academic way of training, consecutive fifths.

"These people, when they do become interested in bells, are astonished to learn that a large bell must have two distinct notes—its 'tap-tone' and that which is called its 'hum-tone.' Their first supposition very naturally is that these two notes should be, one to the other, in the relation of octaves; the hum-tone, it is noticed, is the lower note in pitch. Now, as a fact, there is nothing poorer in tone than a large bell having the tap or percussion note of a stated definite pitch, and the lower, or hum-note accompanying it, an exact octave deeper. On the contrary, and in defiance seemingly of harmony, a fine bell with the percussion or tap-tone, say E, should have its lower, or hum-tone, a major seventh below, but flattened to about the extent of a quarter of a semitone; broadly speaking, its pitch should be F rather flat, and this tone, forming a peculiar interval with the E above, although it might be supposed to be discordant, really gives the best possible result that can be had from a bell, and the musical ear is always seeking that combination of two blended tones when the true ancient bell tone has been appreciated. There are many harmonics heard, but these we pass by, as they are quite subordinate in strength.

"It would be a mistake to regard this deep tone as in any sense harmonic or depending upon the tap-tone, for the tap-tone obtains its pitch from the metal and the way in which the bulk is disposed, whilst the hum-tone is due to the relative proportions of the shape given to the bell, and the reason for the choice of the particular pitch it should have, is that these large bells, when the hum-tone is an octave, give unsteady sounds—confused and wavering, and long experience has led founders to perceive that this flattened major seventh best steadies the bell sounds, and seems in some way to absorb discordances.

"The music-master may possibly know many things in questions of sound, yet not be practical. It is of no use bringing his theories and logic to the bells. The bells make their own theory, and decide the practical utilities that should attach to their use. Thus there are still distinctions to be observed. In a peal of church bells having eight notes,

the treble might be E and the tenor E, and the whole of these bells would be satisfactory, each bell with its hum-tone related to it as described. Now higher than this treble E the hum-tone makes itself as powerfully noticeable as the tap-tone, and it is at this point quite obvious that smaller bells should hum their octaves, and in this way content the ear. For, supposing further that a peal is one of ten, and that the F sharp and G sharp are introduced, completing the series, then, these bells having tap-tone and hum-tone of equal telling power, it would be impossible for them to sound otherwise than out of tune, if their flattened major sevenths were present in strength; and this is where so many difficulties arise in this country with small bells in ringing peals, because the distinctions which should be observed at different parts of the scale have not been understood, or the effects appreciated.

"Bells above the E mentioned, or if in a carillon, may be extended to C, all with their two tones an octave apart. So also the compass may be carried higher to the smallest bells possible with good effect.

"As bell-founding with me is a thing of the past, I may mention, without appearance of advertisement, that I have cast several sets of bells in perfect tune, by which I mean they have not been touched after casting. The largest was a set of eight for the Church of St. Andrew, Wells Street, London, the tenor being twenty-one hundredweight.

"In my method of setting out bells, I had no difficulty whatever in governing the hum-tone in connection with the upper note, as to whether it should be a major seventh flattened or the octave, it being entirely determined by the width of the upper part of the bell in relation to the lower or great diameter."

Now, what Mr. Lewis says about bells making their own theory surely proves my own case, as it is the basis on which I have laid down the lines for the better tuning of bells. I have made an analysis of the bells of St. Andrew's, Wells Street. They are indeed a good peal according to the ordinary method of tuning, but the hum-notes are by no means regular, which seems to point to the fact that Mr. Lewis found difficulty in regulating them. As a matter of fact, only two of the bells satisfy his own conditions just mentioned, the hum-notes of the remaining six being less than the major seventh below the strike note. Again, surely if it is necessary to have the hum-note a perfect eighth below the strike-note in the smaller bells, it is equally necessary to have them so in all the others. I must say, that a hum-note a seventh below the strike note does not seem to me in any way to steady the bell sounds, or to absorb discordances, as Mr. Lewis states. As to the hum-note (when a perfect eighth below the strike-

note) causing the bell to give "unsteady sounds, confused and wavering," the very opposite of this is the result of my experience.

It is curious that the notes contained in a bell do not produce beats as one would expect, they seem to vibrate in different spheres; but, of course, in sounding bells together the beats are distinct enough. A bell in tune with itself may have a poor tone, on account of wrong thickness proportions. There are many such bells on the Continent.

I have continually referred to Continental bells because so much nonsense has been written about their superiority. True it is that there were famous makers in the sixteenth and seventeenth centuries, such as Van den Gheyn, Hemony, and Du Mery, who tuned their bells according to the conditions I have named, which conditions are to be found in all the best bells. The secret of their tuning seems to have been lost for centuries, as in all modern Continental bells (in fact those cast during the last two centuries) there is little difference between the tuning of theirs and ours.

Of course, it is simply absurd to compare the effect of ringing bells with carillons, as the sound of swinging bells is so different from that of bells hung dead and hit with a hammer.

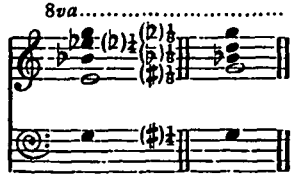
And now, in order that you may have an opportunity of judging between the ordinary method and the true method of tuning, here are two bells placed at my disposal by Messrs. Taylor, of Loughborough.

(1) Tuned according to the old system by a well-known London firm of bell-founders.

Date, 1900.

Diameter, 2 feet 2 inches.

Note, G.

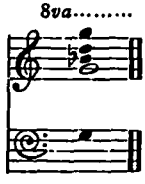


(2) Tuned according to the conditions I have laid down.

Date, 1901.

Diameter, 1 foot 11 inches.

Note, G.



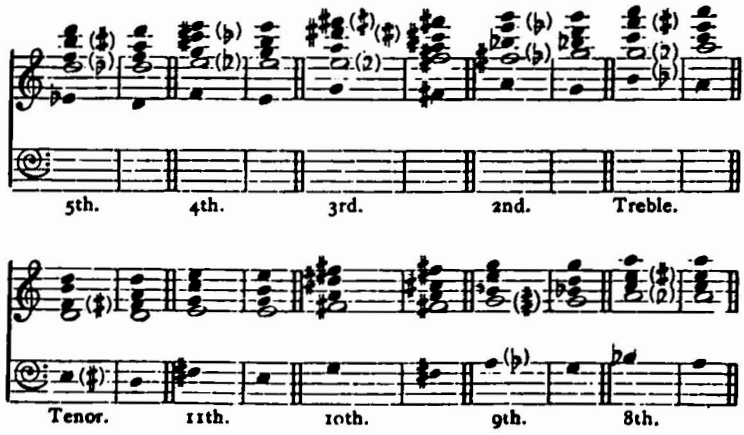
These shall be sounded in succession, and you can decide easily for yourselves which is the better bell of the two.

In conclusion, I must tender my very grateful thanks to Messrs. Taylor, of Loughborough, for much information, and for sending these bells here for my use. They have kindly assisted me in every way, and are just as keen as I am in placing before musicians the results of their work and experiments in perfecting the tuning of bells. In my own mind there is no shadow of doubt as to which is right and which is wrong. I have never yet heard any argument whatever that can in any way interfere with this better system of tuning, and I feel confident that this system must eventually commend itself to all who have to deal with bells, not only to bell-founders, bell-tuners and musicians, but to the whole of the musical public.

APPENDIX.

Since this paper was prepared, an interesting correspondence has taken place respecting the well-known peal of twelve bells at Painswick, which were recently re-hung, and which I had the opportunity of thoroughly testing.

That they required re-tuning there can be no possible doubt, as the following diagrams will prove. Strange to say, the Church authorities were quite satisfied as to their perfect tune, and against the best of advice retained them in all their discordant loveliness.



DISCUSSION.

THE CHAIRMAN. — Ladies and Gentlemen, I am sure you will all agree in passing a hearty vote of thanks to Mr. Starmer for the very interesting and instructive paper which he has read, and to Messrs. Taylor for bringing the bells. (This was passed unanimously.) Bells are musical instruments, although some persons perhaps do not rank them in that category. I may remind you that many composers have made effective use of bells in their music. If I remember rightly, Meyerbeer uses one with startling effect in the "Huguenots," it sounds the tocsin for the massacre of the Protestants. Later than this now neglected opera, we have had two remarkable examples, one is in the beginning of Sir Arthur Sullivan's "Golden Legend." There, practically the whole movement is founded on a theme given out by the bells, and afterwards used in the storm episode; then, when this is over, and the devils are driven off, we hear the bells joyfully join in with the orchestra in the finish of the movement. There is a remarkable overture by Tschaïkowsky in which the bells are used with terrible effect. It was played at the Crystal Palace not very long ago, and when I heard the tolling of the bells, mingled with the drums and the gong, I thought it was one of the most fearful dins I ever listened to. The composer says it is to represent the clanging of the bells in Moscow during the fire that broke out in that city. I should not omit to mention the exquisite use made of the little bell in Sterndale Bennett's beautiful "Paradise and the Peri" overture, the prison bell in "Trovatore," and the goat bell in "Dinorah"; and I need scarcely remind you that the carillon is the convenient representative of a scale of bells in the orchestra; nor need I detain you with any remarks on the fine carillons with the important music written for the bells still to be heard in Holland and Belgium. Under the classification of ancient bells must be included vibrating cups or plates, as we now find in Burmah and Java. Sir Frederick Bridge has made a happy use of these in his charming "Callirhoë" cantata, founded on the old classical legend of certain golden bowls hung up in a tree moved by the wind, and mystically conveying advice to those who sought the shrine of the nymph. It is therefore certain that bells must be regarded as musical instruments, quite independently of their ordinary use in calling persons to church. Possibly, now that watches and

clocks are so common, bells are not quite so necessary for reminding us that the service is about to begin; but, despite occasional complaints, I am sure musicians would be the last to desire to see them removed from our Churches. As the lecturer has said, the most important thing in their musical construction is the harmonics they give out. You must all have observed how bells differ, not only in their quality of tone, but also in the settled fundamental sound given out. If we can get the harmonics rightly to agree with the strike-note of the bell and blend with it, then we have a bell which is satisfactory to our ears—one of the two you have heard this afternoon, I think, proves this amply. There is one little exception I must take to Mr. Starmer's paper. It is that in speaking of the history of bells and their use he referred to those little ornaments which are in the shape of bells, and which he seemed to regard as little more than ornaments. I daresay you know there are many very ancient bells in existence. I have heard, in the museum at Berlin, two old specimens. They were taken from one of the Babylonian tombs; these were of small hemispherical shape. It is not easy to get a German custodian to do anything which is "verboten," but he did open the case for me, and it was very interesting to reflect that I was hearing the sound of a bell which had, perhaps, been used in the worship of Bel; its age was not less than 5,000 years. It is true that the bell is nothing more than a bent-up plate of metal. Professor Tyndall, in his famous lectures on sound, at the Royal Institution, gave many illustrations of vibrating plates. I am sure if he were alive—he was an old and valued member of this Association—he would have been able to tell us something more about bells. I remember very well he showed that, by making his plate vibrate with a violin bow, and putting his fingers at different points, he obtained different tones. What he did, of course, was to stop certain lines of vibrating harmonics and let the others sound out more clear and distinct, and thus materially alter the tone. As I understand our lecturer, this is exactly what happens when, by altering the thickness of different portions of the bell metal, practically we change the harmonics which enter into and affect the quality of the tone. The improved method of manufacture which Mr. Starmer has shown, should be of value and interest not only to us, but to manufacturers. Probably, years ago, bells were made by rule of thumb, but now it is all reduced to a system, and it is pretty evident that after making proper calculations and arranging dimensions before the metal is poured into the mould, they know exactly what they will get. As to bells being out of tune with one another, I must confess this is a very difficult thing to determine. I well remember the

excitement when the new bells were put up in St. Paul's Cathedral. There was a long correspondence about them in *The Times* newspaper, started by the Rev. Mr. Haweis. He mightily approved of the foreign bells, and condemned our English make; he said most extraordinary things about their pitch and their notes, and people began to fear there was something very wrong about these bells. But a much greater authority than Mr. Haweis appeared on the scene—the late Sir John Stainer contradicted his statements, and set the whole matter right in public estimation. Poor Haweis had nothing more to say; he did not rightly appreciate the true intonation, or know the harmonics given forth. There we had a scientific musician who was able to tell us from his absolute knowledge what Mr. Haweis only guessed at. There is one thing which I hoped our lecturer would have been able to tell us, but he did not—perhaps he can do so in his reply to our discussion. I mean the reason why harmonics which arise from a bell differ from the harmonics which come from the agitation of a string, or on blowing a wind instrument. Their giving out of a minor instead of a major third must at once strike musicians. I cannot conceive why it is. The hum-note, which we all hear when the bell seems to settle down, one would think must be a resultant tone, but so far as I can work it out, it does not seem to follow the law of resultant tones. I am sure you all know that this is merely the product of subtracting the vibrating numbers from one another. I am not certain whether that law is absolutely correct and works out quite right with regard to the strong resultant tones formed on the harmonium. There is another thing I should like to know, if I may trespass so far, and that is why the pitch of the bell should flatten, as happens when it is beginning to slow down. You hear a bell which speaks, say, E, but when the sound begins to die away it no longer sounds a true E; perhaps sections of it speak independently, and perhaps through varying thicknesses they do not agree, so we get the well-known effect of beats. Possibly the bell divides into two hemispheres which are not quite equal; however, I do not know, and hope we shall hear something satisfactory on this phenomenon.

Mr. Blaikley.—I have no doubt Mr. Starmer would, in replying to Mr. Southgate, say anything I might say; but if he will excuse me, I would make one suggestion with regard to one of Mr. Southgate's remarks about the hum-note. I am not a bell-founder myself, but supposing this g^{I} to be the lowest appertaining to the bell, then the difference tone between it and the d^{I} would be g, the octave below the g^{I}, which is the hum-note. And again, the difference between that g^{I} and the upper g^{II} would also give g.

THE CHAIRMAN.—But where the hum-note is a semitone out—

Mr. BLAIKLEY.—The principal notes are not tuned properly. But I should like to ask Mr. Starmer whether there is ever a still lower hum-note discoverable as the resultant of other harmonics.

Mr. STARMER.—I do not know of any such. The components do not interfere with each other in the way you would expect.

Mr. BLAIKLEY.—It appears to me, in listening to bells, that you hear the beats very strongly—we heard them this afternoon—

Mr. STARMER.—Yes, when bells were struck together. When struck singly this was not so. The semblance of beats was due to the moving of the bell produced by the blow of the hammer. Given a stationary bell, then the different tones, whether in or out of tune with each other, do not produce beats, a most extraordinary thing.

(The bells were then struck to prove this.)

Mr. BLAIKLEY.—Is the hum-note a resultant tone?

Mr. STARMER.—No. The hum-note is one of the tones of a bell which can be tuned in the same manner as the third, fifth or eighth.

Mr. BLAIKLEY.—One point, perhaps, it may be interesting to note, with respect to the development of a plate into a bell. There is one very distinct difference in the vibration. A plate vibrates in nodal lines. The opposite sectors rise and fall alternately, but there is no vibration at any part of a nodal line, even where it meets the boundary of the plate. Assuming that we are dealing with a circular-plate, directly this is dished, the circumference becomes a hoop or sound bow, and the vibration is no longer simply up and down at the different segments. When vibrating with four segments the circle becomes an ellipse, with the major and minor axes alternately in opposite directions, and, while at the extremities of the two axes there may be a motion only inwards and outwards, at the angle of forty-five degrees from each of these there is a motion tangentially. That is the one essential difference, so far as I know, between the vibration of the bell and that of a flat plate. As to the question of harmonics, present or absent, I think that is more a question of thickness than anything else.

THE CHAIRMAN.—What Mr. Blaikley says is quite true. I remember very well how Professor Tyndall sprinkled sand on his plates, and though these were made to vibrate and sound, the sand on the nodal lines remained perfectly still. With regard to the resultant tone, I would venture to mention one thing of which I have a vivid remembrance. Sir Frederick Bridge, at one of his Gresham Lectures, had

two anvils brought in. One sounded a fifth above the other. He said, "When you hear these two struck together you will hear the octave below the lower one." He struck them several times, but no lower note came. But at last he got a splendid low note.

Mr. TAYLOR.—I do not think I can add much to what Mr. Starmer has already said, but can confidently state that what we call the harmonic tones of bells are not what is usually understood by that term. They are each principal tones, dependent upon the various curves of the bell. Thus they are not true harmonic tones like those of a string or pipe, as they do not depend upon the fundamental tone, but are to a certain extent independent of each other. It will require a very clever scientist to explain why we have a minor third in a bell. We have paid a great deal of attention to this point, and went to hear the fine large old bell at Erfurt, which is reported to have a major third, but upon carefully testing it found it an exact minor third, and our opinion is confirmed by a German priest who had previously examined the bell, and proves that the lower third was minor and the upper third major.

THE CHAIRMAN.—It is a very hopeful thing to learn that the harmonics are under control, for now we stand a chance of getting more perfect bells. The rise of the minor instead of the major thirds as one might expect is a very curious thing, but it would be useless for us to spend further time in discussing this.

Mr. STARMER.—In speaking of the bells of the Bible, I referred to the evidence we had of those bells, which certainly shows that they were small. You remember, I daresay, the bells on the dress of the high priest; they must certainly have been very small—so small as to have been scarcely worthy of any musical consideration. And then they were made of gold, which, unfortunately, is not a very good metal for sound producing. You have heard regarding the hum-note that it is not a resultant note. I do not think there is a man living who can tell you why the third is minor in Church bells. My aim in this matter has been to bring before musicians the possibilities of these things, and I am quite sure that if anyone hears a bell with the bell-tones perfectly in tune, they will not have the slightest doubt as to which is the better method—to tune one note and let the others go anyhow, or to tune the five. I am sure it rests with musicians to see that this object is achieved. What the Chairman said about the bells of St. Paul's was rather interesting, as the founders of those bells are in the room at the present time. I must thank you very much indeed for your vote of thanks, and I am very pleased that you have taken so much interest in the subject of this paper.