

CAMPANOLOGY

A Handbook for the Carillonneur



Leen 't Hart

Translated by

Hudson Ladd

The University of Michigan

Ann Arbor, Michigan

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CAMPANOLOGY

A Handbook for the Carillonneur

by

LEEN 'T HART

Director of the Dutch Carillon School

and

City Carillonneur of Rotterdam,

Delft, Leiden, and Amersfoort,

The Netherlands

Translated by

HUDSON LADD

University Carillonneur

and

Lecturer in Music

(Campanology).

University of Michigan

Ann Arbor, Michigan, U. S. A.

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This book is dedicated to Mr. H. Molendijk,
former Mayor of Amersfoort, Founder and Chairman
of the Board of Directors of the Stichting Nederlandse
Beiaardschool, in thanks for this contribution to the
Art of the Carillon in general and the Dutch Carillon
School in particular.

Leen 't Hart
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Pictured on the cover is the Bourdon Bell at
Meissen Cathedral, Saxony, Germany. It was cast by
the Schilling Bellfoundry and designed by Paul Börner
of the Meissen Porcelain Factory.

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TRANSLATOR'S PREFACE

This book, written by the Director of the Stichting Nederlandse Beiaardschool, Mr. Leen 't Hart, is the textbook for the school and deals responsibly with Campanology in relation to the carillon. It must be noted that Campanology, the study of bells, is a vast field closely related to Ethnomusicology. The carillon, along with the chime and handbells, is a musical use of bells and is but a small segment of the field of Campanology. This book approaches Campanology from the carillonneur's viewpoint.

Some explanation for the American reader must be given concerning facets of Campanology which are more prevalent in Europe. A visitor to the Low Countries will quickly notice the recurrent ringing of the voorslag, which is simply a musical interval announcing the time. (See Chapter XVI.) The voorslag is the forerunner of the carillon as known today and, presently, it is common to use all or part of a carillon as the voorslag. This

manner of automatic ringing is accomplished in several ways, yet functions as the familiar Westminster Quarters, namely, a time indicator. The music specially written for the voorslag is called a versteek (plural - versteking). (See Chapter XVII.) For lack of English equivalents, the Dutch words voorslag and versteek will be used in this translation.

Another thing noticed by a visitor to the Low Countries is the domineering and beautiful towers which often house a carillon. It was Napoleon who, during his invasion of the Low Countries, took the responsibility and ownership of the towers away from the churches and gave it to the cities. This has permitted the preservation of many towers and has caused them to be a center of civic pride. Along with the towers, many old and sonorous carillons have been preserved which are excellent examples of the early temperaments and workmanship. (See Chapter XXIV.) The difference in temperament is most noticeable when a modern composition is performed on an old instrument.

In this translation I have named the pitches as explained in the Harvard Dictionary of Music as system I. For example, middle c is c^1 , an octave above is c^2 , and an octave below is c.

May I take the liberty to forewarn the American reader to read this book in the context for which it was written, namely as a textbook for the Dutch carillon student. This book offers much succinct information and is to be a stimulus for further independent study of Campanology. When this book was written, Mr. 't Hart did not intend for it to be translated, but it was necessary, for I needed to know the information for my final exams at the carillon school. Furthermore, I strongly feel that it contains much valuable information for the American carillonneur.

In closing, I should like to thank my friend and teacher, Mr. Leen 't Hart, for the encouragement, tutelage, and guidance which he so freely gave. I also thank him for correcting the original manuscript of the translation. Sincere thanks is also extended

to Mrs. Rolf and her daughter, Anneke, for their
valuable assistance in the technical translation.

For the final revision and editing, I wish
to thank Sally Cushing, Larry Weinstein, Rudy and
Sharon Zuiderveld, and Gretchen Tarchinski for
their help and contributions. Most of all, I wish
to sincerely thank my friend, Mr. William De Turk,
for without his advice and assistance this book
would never have been published.

June, 1972

Hudson Ladd

University Carillonneur and

Lecturer in Music (Campanology)

University of Michigan

Ann Arbor, Michigan, U. S. A.

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CHAPTER I

THE DEVELOPMENT OF THE BELL AND CARILLON¹

The bell has been known since antiquity.

Early examples of large bells were made of flat iron, hammered and riveted into a spherical shape.

Smaller bells were cast of a mixture of copper and tin having a dish-like shape. It is possible that the Chinese were the first to cast large bronze bells.

In Peking there is a bronze bell weighing approximately 53,000 kg. Large Oriental bells are not swung, but are struck on the outside. These bells were used musically, for with a system of notation and marked rhythms they could be rung alternately with smaller bells. There is little resemblance, however, between these bells and their Western counterparts.

It seems probable that the origin of the Western bell is from the Near East, for it was there that the necessary techniques for proper

casting in bronze were mastered. The Celts, famous for their founding techniques, shared and broadened their knowledge of casting in bronze during their travels through Italy, Scotland, Ireland, and throughout Europe.

Another possibility is that, before the time of Christ, this knowledge was brought from Asia to the eastern shores of the Mediterranean Sea, then to Africa and Italy. It is known that 600 years after Christ the Italians received bells from Carthage. Carthage, located on the Bay of Tunis in northern Africa until it was destroyed by the Arabs in 698 A.D., was an active marketing center in the sixth century and dealt heavily with its colonies of Sardinia, Sicily, Spain and Gaul. Carthage also traded with parts of Belgium and northern Italy, the ancestral home of the Celts.

It is known that the Romans were well acquainted with the bell because a bell announced the opening of the public baths. A large swinging bell housed in a frame on a wagon was pulled into battle by Roman armies.

The first indication that a bell was used as a summons to a religious gathering was in the sixth century A.D. Nola, in the province of Campania, Italy, has long been called the cradle of the religious use of bells.

In the seventh century bells were used increasingly for religious purposes. It is recorded in Spain that as early as 850 A.D. bells were hung above the roof of a church, either in a primitive frame or in an already existing tower. Soon special towers were built to house bells. Due to the fact that the largest bell was often too difficult to set into motion, it was used only for important festive occasions.

In the eleventh century Theophilus, a German monk probably from Cologne, wrote a manuscript called Schedula diversarum artium² in which he explained in detail the molding and casting process for bells. This document provides an insight into the early stages of the art of bell-founding. It is thought that he also cast bells which, true to the bell profiles of his day, were in the

shape of a beehive and had a clearly perceptible sound-bow. In Germany there are still some 15 examples of this bell profile (i. e., in Iggenbach, Hersfeld and the bell museum in Apolda).

In the twelfth century bellfounders discovered a casting process which allowed for the molds to be separable. This method is similar to that used today. The beehive profile proved unfavorable because the bell was pointed, slender, and sharply conical near the crown.

During the thirteenth century the Gothic profile was developed and, except for minor changes, is still used today. German bellfounders employ this profile today while Dutch bellfounders tend to use the Hemony profile, which is somewhat thicker overall.

Gradually the bell was used for all sorts of purposes. The 'Joy Bell' was rung at times of exultation, such as a triumphal entry into a city, the celebration of a victory, or the signing of a peace treaty. The 'Fire Bell', tolled in event of a

fire and swung in event of a flood, alerted the citizens of impending disaster. In tolling a bell the ringer pulled the clapper against the side of the bell by means of a rope. This was usually done in a forceful manner and many bells were cracked by this method of ringing.

Beginning in the seventh century the 'Hour Bell' was used to announce the seven canonical hours given in the Breviary. At different intervals during the morning, midday, and evening, the 'Prayer Bell' sounded to remind and summon the people to devotions.

The Drabcloche (curfew bell) was rung in the evening as a signal to end the day's work. By the middle of the eleventh century this bell was used in England to announce the time that all lanterns and fires were to be extinguished since many of the English houses were made of wood.

During the twelfth century in France the 'Wine' or 'Drinking Bell' sounded the closing hour for taverns.

The evening peal developed a religious significance in that its sound alerted the citizens to repeat the "Hail Mary" three times.

During the fifteenth century the morning peal continued until the beginning of the early Mass.

In the eighth century the 'Death Bell' was tolled in such a manner as to distinguish the passing of a man, woman, or priest. During the Middle Ages it was thought that ringing a bell at a funeral was an act of exorcism.

Today an example of a 'Storm Bell' can be found in the Belfort in Ghent, Belgium. The inscription on the bell says:

"Myn naem is Roelant, als ick kleppe dan ist brand,
als ick luye, dan ist storm in Vlaenderlandt."

My name is Roeland, when I toll there is a fire,
when I peal, then there is a storm in Flanders.

It is apparent from this summary that the bell has long been functional as an announcer, both sacred and secular.

It was fashionable to have smaller bells inside the home. Old manuscript miniatures often portrayed men, sometimes a monk or even King David, ringing bells. Sitting in front of or standing under four to eight little bells hung in a row or arranged on a hoop, with hammers in their hands they are playing the bells. Currently there are two methods of bell ringing which are related in some degree to this earlier method. The first is the handbell which, with attached clapper and hand-grip, is picked up and rung by a quick wrist movement. Within the last decade handbell clubs have become very popular in North America, especially at churches and universities. The second method is that of English change-ringing which, after a ringer has been assigned to each of the ^{Six}~~eight~~ to twelve larger bells, the bells are allowed to swing in a specified mathematical progression.

A large amount of manpower was required for the ringing of the bells in a large continental peal. For instance, in the Dom Tower of Utrecht there are seven large swinging bells which were

cast by Geert van Wou in 1505. The largest bell, Salvator, weighs approximately 8,200 kg., and the weight of the seven bells together totals approximately 26,000 kg. When a peal was rung on all seven bells it was necessary to have, before the modernization of the bell frames in 1928, 54 men employed as ringers. For the Salvator bell alone it was necessary to have two teams of 16 men each.

It is common today to use the largest bell in a peal as the hour bell connected to the voorslag and also as the bell to summon the people to a religious service. In the Protestant churches this bell was rung only on Sunday while the Catholic churches would often ring their bell for the daily mass and for other purposes such as the Angelus.

Many different harmonic or melodic combinations are possible when a peal contains two, three, four or more bells. For example, a peal of two bells may have:

- a major second interval (melodic), or
- a minor third interval (harmonic), or
- a major third interval (harmonic).

As an example, a peal of three bells may consist of melodic:

c - d - e, c - e-flat - f (very good), c - d - f (good)

or harmonic: c - e-flat - g, c - e - g.

A peal of four bells may be:

c - d - f - g, or c - e-flat - f - g (better).³

It is interesting to note that the use of minor seconds and augmented intervals in a peal are seldom found in the Netherlands while they are fairly common in Germany. However, there is a minor second interval in the peal of the Eusebius Tower in Arnhem.

¹ Translator's note: This first chapter is intended to give the reader a sampling of the fascinating history and genesis of the bell and to prelude the remainder of the book which deals responsibly with one aspect of the musical use of bells, namely the carillon. Each campanological authority may have written this chapter differently but the translator feels that it accomplishes its task of being an introduction to the study of bells.

² Author's note: First edition of this manuscript may be found in the British Museum.

³ Author's note: Wolfgang Amadeus Mozart was interested in promoting major peals.

CHAPTER II

THE CARILLON

The Dutch word for carillon is beiaard,¹ which evolved from the old Dutch words of beyeren and beyaarden and later developed into baren or beren, meaning sound-givers. The word carillon evolved from the old French word quadrillonner which meant the three bells of the voorslag plus the hour bell, totaling four (quatre) bells. Later this was called carillonner.²

It is reasonable to believe that the first bell players were those in charge of the tower and bells. On festive occasions they would make a lively use of the bells by striking the outside of the bells with a wooden hammer or, by means of ropes tied to the clappers, ring the bells alternately. The automatic ringing of bells developed from the first method while the personal and artistic playing of bells evolved from the second method. The second manner of bell ringing, in

which the hands are connected to two bells by means of ropes, and the feet, by use of a pedal system, are connected to two bells, can still be observed in Switzerland and Italy.³ (Lit. "Cloches et musique" by Marc Vernet)

Bells have long been used as time indicators and announcers but thanks must be given to the voorslag for the musical and artistic expression on bells. Before the voorslag came into existence the hours were announced by the proper number of hammer strokes on the largest swinging bell. But it was discovered that in order to draw people's attention to the first stroke of the hour, a warning must be given. The pair of smaller bells sounding this warning was called voorslag (before strike) or wekkering (alarm). Originally, it was the duty of the tower watchman to strike these smaller bells before he struck the hour. However, as clocks were installed into towers, men quickly discovered means by which this could be done mechanically. In order that this be accomplished a ton (barrel) or trommel (drum) was installed in

the tower along with the clock. The early drums were made of wood into which pegs were driven. As the drum slowly rotated the pegs would move against levers which were connected to hammers by iron wires. As the levers fell from the pegs, the hammer would fall against the side of the bell. In 1371 a clock and voorslag was installed and used in the tower of Middelburg. It was common that the bells of the voorslag be hung in the openings of the bellchamber containing the swinging bells so that they could be seen and clearly heard. Gradually the number of bells in a voorslag increased to a scale of eight diatonic tones. As time passed and the voorslag grew proportionately, it was discovered that the window-openings of many towers were too small and therefore the bells were hung inside the tower. In many steeples they filled the entire structure. Some were even enlarged to 20 bells.⁴

A few towns which had such an early mechanical voorslag were Louvain (1381), Mons (1382), Haarlem (1412), and the City Hall in Leiden (1460).

Clocks were previously installed in the towers of Middelburg (1371), Mechlin (1372) and Ghent (1376).

In Belgium the voorslag was given the nickname rammel (racket) which seems to indicate that they were less than satisfactory reproducers of melodies.

There is evidence to confirm that the first console⁵ was attached to the voorslag of Oudenaarde, Belgium, in 1510. Consoles were later installed in other cities. In Mechlin the console was added to the voorslag in 1556, and, in the same city in 1583, the first pedals were added making it the first console as it is known today.⁶

As previously stated, the first automatic player drums were made of wood. Jan van Call from Nijmegen brought the first copper drum to the Nieuwe Kerk in Delft in 1663, where it is still in use today.

When the Hemony brothers began casting their carillons in 1644 many cities wanted their

voorslag replaced by a carillon. It was not uncommon for the richer cities to have more than one carillon: Enkhuizen, Haarlem, Rotterdam, and Veere each had two; Middelburg, Zierikzee, and Alkmaar each had three; and both Utrecht and Amsterdam had five.

During the latter half of the seventeenth century Francois and Pieter Hemony cast and enlarged more than 50 carillons, with more than 30 of these being in what is known today as the Netherlands.

About the year 1600 a carillon contained, on the average, only 22 bells. But between 1600 and 1700 the average grew to between 32 and 38 bells. Around 1900 the carillon grew to have between 38 to 48 bells (3-1/2 to 4 octave range) but almost always omitting the two lowest semitones.

Recently there have been some carillons cast for the Netherlands with a range of 5 or more octaves (Philips carillon in Eindhoven), as has been the case in North America for some time.⁷

Carillons are often transposed instruments.⁸

It is not recommended that the transposition be more than a minor third in either direction for both heavy or light carillons. For example, the c^1 of a heavy carillon may be connected to a bell with an actual pitch of 'a' or upward to a bell sounding 'e-flat¹'. Since Dutch bellfounders are capable of making such beautiful small bells, it is possible that this same transposition be made on light carillons, although, as a rule, it is not recommended that a light carillon be transposed even higher.

¹ J. Veering, Delftse Hogeschool: An acceptable pronunciation of beiaard is (bay-yart). However, for the linguist, it must be explained that the word contains two syllables. The first (bei-) has a diphthong which is pronounced as an a (like in bad) plus an ee (as in teen) = b-a-ee; and the second syllable (-aard) is pronounced as yard, with a slight roll on the r and the d replaced by a soft t.

² Translator's note: Not to be confused with the performer, carillonneur.

³ Translator's note: This method of bell ringing is closely related to the Russian Zvon and the modified chiming or change-ringing apparatuses found in some Anglican churches.

⁴ Translator's note: It follows that as the voorslag grew in number of bells, men soon discovered that popular, folk, or hymn tunes could be installed on the drum to sound the hour stroke warning. See Chapter XVII.

⁵ Translator's note: The early carillon consoles were only keyboards. It is common practice in North America to name the apparatus on which the carillonneur plays the console. In the past it has been called the clavier which gives the erroneous impression that only a keyboard is involved. The carillon console today consists of both a baton keyboard and a pedalboard.

⁶ Author's note: Although extremely primitive by today's standards.

⁷ Translator's note: It is of interest to note that long before the relatively late advent of the carillon in this country, chimes were popular in churches and universities. It was thought that the early North American carillons were simply enlarged chimes which were connected to a more sophisticated console. Since the early 1920's, when the first carillons were imported to this continent, they have grown in popularity to such a degree that there are now about 150 carillons in the United States and Canada.

Many large carillons have been cast in England by the John Taylor and Co. Bellfoundry or the Gillett and Johnston Bellfoundry. A few carillons have been cast in North America by the Meneely brothers of Watervliet and Troy, New York.

⁸ Translator's note: For an example of carillon transposition, observe The Charles Baird Carillon at The University of Michigan in Ann Arbor, Michigan. Middle c on the console sounds, in actual pitch, an a-flat below. Therefore, this carillon is transposed down a major third. When a full description of a carillon is desired it is necessary to state both the keyboard pitch and the actual pitch of the bourdon (heaviest) bell.

CHAPTER III

CARILLONNEURS

It is difficult to name the first carillonneur; however, there is evidence that he may have been Jan van Bevere, who in 1477 played music on the small bells in a tower in Dunkirk, France. This is authenticated by his descendant, Dr. G. Van Doorslaer.

Since the sixteenth century there have been carillonneur appointments in the Belgian cities of Bruges (1532), Antwerp (1541), Louvain (1548), Ghent (1553), and Mechlin (1557).

During the seventeenth century in the Netherlands, appointments were given at the following cities:

Amsterdam -- Salomon and Anton Verbeek,

Jacobus van Noort,

Michiel Nouts,

Michiel Nuyts and

Dick van Neck;

Arnhem and Delft -- Dirk Scholl;

Delft and The Hague -- Cornelis Scholl;

Leiden -- David Slechtenhorst;

The Hague -- Quirinus van Blankenburg;

Utrecht -- Jonkheer Jacob van Eyck.

(Jonkheer indicates membership
in the nobility, albeit low.)

During the seventeenth century Belgian
carillonneurs were playing at:

Brussels -- Theodoor de Sany (A book of
verstekingen¹ which he wrote
has been preserved, dated 1648.);

Brussels -- Pauwel Nijs;

Mechlin -- E. Bonnejonne, 1637-1686, who
bought a total of 33 bells from
Pieter Hemony for the St. Rombouts
Tower in Mechlin.

A few of the carillonneur appointments in the
Netherlands during the seventeenth century were:

City Hall of Amsterdam -- Jacob Potholt
(born blind in 1723);

Delft -- Johan Berghuis² and his son, F.J. Berghuis.

Below is a short list of Belgian cities that employed a carillonneur during the eighteenth century:

Ghent -- Peter Schepers

Ghent -- Pieter J. Leblan

Aalst -- Boudewijn Schepers

Antwerp -- Joannes de Gruytters

Mechlin -- Jan Jozef Colfs

Louvain -- Matthias van den Gheyn

The nineteenth century was a period of decline for the art of the carillon.³ In Belgium there is only one important name, Adolf Denijn, whose son, Jef Denijn, succeeded him as carillonneur at the St. Rombouts Cathedral of Mechlin in 1881. In 1892 Jef Denijn began playing his famous summer evening carillon recitals which gained great popularity with the public.⁴ This is considered by many to be the rejuvenation of the carillon art. In 1922 Denijn began the first carillon school, in Mechlin.

After 1900 a greater interest in the carillon appeared in the Netherlands. Listed below are a few places where regular recitals were given earlier in this century.

Delft and The Hague -- J. A. Zwaan

Rotterdam -- W. C. de Lange

Nijmegen -- W. de Vries

Leiden -- L. Mens

Utrecht -- J. A. H. Wagenaar

Ferdinand Timmermans, City Carillonneur of Rotterdam until his death in 1957, was the first Dutchman to receive a diploma from the Mechlin Carillon School in the year 1925. Listed below are a few of the early Dutch carillonneurs who also received their diplomas from Mechlin.

's Hertogenbosch -- Toon van Balkom

Zwolle and Kampen -- Willem Créman

Amsterdam and Barneveld -- C. Roelofs

Bergen op Zoom -- A. J. de Groot

The more prominent Dutch carillons and carillonneurs after 1945 are:

Utrecht -- Chris Bos

's Hertogenbosch -- Sjef van Balkom

Delft and Leiden -- Rein Ritter (later also
in Alphen a/Rijn and
Rijswijk)

Delft, Leiden, Amersfoort

and Rotterdam -- Leen 't Hart.

Since the establishing of the Dutch Carillon School in Amersfoort in October, 1953, there has been a new generation of carillonneurs. More than 30 students, from the Netherlands, Germany, Denmark, Sweden, Switzerland, Spain and the United States, have returned home with their Practical and/or Final Diplomas since the founding of the school.

¹ Translator's note: See Translator's Preface for definition of verstekingen.

² Translator's note: Composer and compiler of the Berghuis Collection recently rediscovered in the City Archives of Delft.

³ Translator's note: As with all of the arts, religious and political conditions have had a sharp influence on the art of the carillon. It has taken several decades to replace the bells lost during the last World War.

⁴ Translator's note: The Monday evening recitals were so popular that later, special trains converged on Mechlin from Antwerp and Brussels bringing tourists and carillon enthusiasts.

CHAPTER IV

CARILLON MUSIC

The earliest known example of music written or arranged primarily for the carillon (or voorslag) is the Versteekboek¹ of Theodoor de Sany, dated 1648.

A more important example of early carillon music is the collection by Joannes de Gruytters (1709-1772), City Carillonneur of Antwerp from 1740 presumably until his death. This collection contains 194 works of original carillon music, arrangements of harpsichord music, and songs. Its official title reads:

ANDANTES

marches, gavottes, Arias, giges

Courantes, Contredanses, Allegros,

preludes, menuets, trios, etc.

FOR THE CARILLON OR BELL-PLAY

collected and arranged

by me

IOANNES DE GRUYTTTERS

Carillon or bell-player of the city and Cathedral

of ANTWERP

1746

Contained in this collection are carillon compositions by Colfs, Schepers, De Wever, De Croes and arrangements of other works by De Fesch, Baustetter, Locatelli, Renotte, Raijck, Fiocco, Corelli, Vivaldi, Couperin, and Handel.

Also included are a number of works which do not mention the composer's name; it is considered that some of these may have been written by de Gruyters himself.

Preserved and recently found in the City Archives of Delft are 14 little volumes of

arrangements and transcriptions for the carillon by Johan Berghuis (1725-1802).

Matthias van dan Gheyn (1721-1785) of Louvain wrote ten plus one (the Cou Cou) original carillon preludes² in addition to a few other works.

Adolf Denijn (1824-1894) of Mechlin wrote variations over Ik zag Cecilia komen (I saw Cecilia coming).

Jef Denijn (1862-1941) composed the Prelude in B-flat, Prelude in G, Ave Maria, and Andante Cantabile (theme with variations).

Jef van Hoof (1886-1959) of Antwerp, for a long time the theory teacher at the Mechlin Carillon School, wrote a Prelude, Menuet, Intermezzo, Sonata (in one movement), Preludium quasi una Fantasia, and Pedal study in the form of a Suite.

Staf Nees (1901-1965), also from Mechlin, wrote many compositions for the carillon.³

Other Belgian composers who have written

for the carillon are: Kamiel Lefevere, Paul
Gilson, Jules Vandeplas, Arthur Meulemans,
Geo. Clément, Piet van den Broek, Chris Dubois,
R. Defossez, Gaston Feremens, J. Lerinckx,
Edw. Loos, A.v.d. Moortel, and Eugene Uten.

Carillonneurs and composers in the
Netherlands have also written for the carillon.
Among them are: W. de Vries, J.A.H. Wagenaar,
Willem Créman, Fred. Timmermans, B.J.
Franssen, Gerard Boedijn, Henk Badings, Sjef
van Balkom, Wouter Paap, Leen 't Hart, Jac.
Bonset, Chris Bos, Wim Franken, Albert de
Klerk, Anton van Ooik Willem Piper and Willem
Vogel.

Composers and carillonneurs in other
countries who have written for the carillon are:

France -- Jacques Lannoy

England -- Clifford Ball

Ireland -- Staf Gebruers and

Aloys Fleischmann

United States -- A.L. Bigelow, John Cage,
James Lawson, Fred
Marriott, Wendell Westcott,
Percival Price, and
Raymond Keldermans.⁴

Published carillon music is available from
the Mechlin Carillon School, Dutch Carillon School,
Alumni Association of Mechlin, Donemus (Peters
Edition in North America), Nederlandse Klokkenspel-
Vereniging (available through Donemus), and The
Guild of Carillonneurs in North America.

¹ Translator's note: See Translator's Preface.

² Translator's note: Considered by many to
be as important to the carillon repertoire as Bach's
Preludes and Fugues are to the organ.

³ Translator's note: See "Survey of Basic
Carillon Repertory" by Leen 't Hart.

⁴ Author's note: These lists represent
only a few of the foremost carillon composers.
In no way is it to be construed as all-inclusive.

CHAPTER V

HISTORICAL SURVEY OF THE BELL

The cymbalum, mentioned in Psalm 150 and used before and during the time of Christ, is now superannuated. It was a percussive instrument made of hollowed-out wood or metal and shaped like a disk. It sounded only when several were shaken together. Except for being considerably smaller and more concave (bringing it a little closer to the accepted bell shape), it was much like the cymbal today. During the Middle Ages, therefore, the name cymbalum was also given to bells. Sometimes they were attached to short handles so that a pair of them could be held in one hand, as often seen in old portraits.¹

Earlier the word cymbalum was also used for the symantron.²

During the Middle Ages the little bells which were often called cymbalum did not have clappers, but rather were struck by little hammers

or rods made of either wood or metal. During this same era the word nola was used for the larger swinging bells. A more common name for a church bell was campana or clocca. Perhaps the origin of the word nola is the town Nola in Italy, but another possibility is that the word developed as a diminutive of campana (swinging bell), campanula--campanola--nola.

Another name for the campana was tintinnabulum. (Tintinnire, metallic sound giver, tin-tin-tin.)

The composition of the bell bronze was and still is today approximately 80 percent copper and 16 to 20 percent tin. This composition appears to be ideal in that the bell receives nearly the maximum in resonance and durability.

Throughout the Middle Ages the cymbalum had a rounder form³ but later developed into a tulip-like shape, from which the Gothic profile evolved.

¹ Author's note: The Dutch word for cymbalum that are attached to a handle is stangbekkens.

² Translator's note: The symantron is a wooden plank or a metal beam which, by using wooden or metal hammers, is struck with variations of rhythm and intensity. Used primarily in the Orthodox countries.

³ Author's note: Sometimes called the romantic form.

CHAPTER VI

USE OF BELLS DURING THE MIDDLE AGES

It was common that small bells were hung on poles or beams.¹ They would number between three and eight bells comprising a scale of, for example, c - d - e - f - g - a - b-flat - b. Occasionally the b-flat was omitted and the octave completed. Since it was often necessary to play a note outside of this range, octave reciprocation was commonly used.

These bells were used as an aid for interval instruction and, in large churches and cloisters, as an accompanying instrument so that the organ could better assume the role of a liturgical instrument.

The organ and cymbalum were often played together. Organ registrations during the Renaissance called for cymbalum, cimbeln, or cimbaal.² In 829, when Charles the Bald was received into Reichenau, a festive hymn was used which called for organum cum cymbalum.

The cymbala was also installed in church towers. The oldest example of such a bell-play in the Netherlands is probably at the Abbey of Egmont. Abbot Franco (1182-1206) had the bells brought to the Abbey and Abbot Florens (1271-1304) had them renovated. The origin for such usage of bells can be traced to Christian cloisters in North Africa.³

The Bible mentions little bells of gold attached to the hem of Aaron's priestly robes (Exodus 28: 33, 34). Bells were also used to adorn horses as well as for other ornamental purposes (Zechariah 14:20). The cymbala, as mentioned in I Chronicles 13:8 and 16:42, II Samuel 6:5, was used as the accompanying instrument for the choruses of the Levites.

The Greeks, from approximately the second century B. C. until 350 A.D., were also known to adorn their horses with bells. It was thought that by wearing bells a horse would become accustomed to noise and, hence, be better fit for battle.⁴ Plutarch recorded that "the time of the evening meal [was announced] on one bell at the market

place." Traditionally the bells in Athens were rung by priests. Also, a small bell was hung around the neck of a criminal as he was brought to the place of execution.

From 509 B. C. until 476 A. D. the Romans used bells for various reasons. One of the ways in which the bell was used was for announcing the opening of the public baths.

"The bell of the warm bath rings
stop your ball playing
if you want to be washed by a maid
before you go home."

The guards atop the city walls also had bells which they rang to alert the citizens of approaching danger.

It is thought that the first use of bells to announce a religious gathering was in Nola, Italy, during the reign of Bishop Paulinus.

The French have also been long acquainted with the bell for "when in the year 710, Chlothar, King of the Franks, laid siege to Orléans, the

Bishop of the above mentioned city had the bells of St. Steven tower rung, which the enemy heard and were so frightened by this unknown sound that they became confused, which quickly ended the seige."

In England it is recorded that Turkerukuse, the Abbot of Croydon, died in the year 875. At the monastery of which he was the founder, six bells were rung to mark his passing. "Two large, two medium, and two small [bells], which he previously had had cast and the above mentioned were wonderfully in agreement with each other."

It is certain that bells were used in Germany for religious reasons; in the year 1300 the Synod of Cologne decided that only literate men could be promoted to klokkenaars, men of bells, and therefore able to assist the priest in serving the Mass.

The domain of the bell is certainly not limited to Europe. Dampier recalls in his book Trip Around the World that the East Indians had a somewhat unique method of ringing a bell. While

visiting Mindanao, the second largest of the Philippine Islands, Dampier accompanied a general to the Governor's palace where they "came across a row of 16 little bells without clappers, each weighing from three to ten pounds. These were set on a table and the Governor would hit them with a wooden stick. What a great noise they made."

The Pien Chung,⁵ a set of 16 bells hung on a frame, is originally Chinese and can be seen in old photographs. (See Memoire sur la musique chinoise by Mgr. de Bertin, 1776, and Chinese music in the Elsevier Encyclopedia.)

Literature:

Timmermans, Luidklokken en Beiaarden in Nederlands
(Swinging Bells and Carillons
in the Netherlands)

Smits van Waesberghe, Klokken en Klokkengieterij in de Middeleeuwen
(Bells and Bellfounding in
the Middle Ages)

Fischer, Verhandeling van de Klokken en het Klokke-spel
(A Treatise on Bells and Bell-Play)

Rottiers, Beiaarden in Belgie
(Carillons in Belgium)

Lehr, De Klokkeng^eiters Hemony
(The Bellfounders Hemony)

¹ Author's note: These bells were struck with a light hammer.

² Author's note: Not to be confused with the cimbalom which is a stringed, trapazoidal-shaped instrument of the Hungarian gypsy orchestra which originated from the 18th century mincing board.

³ Author's note: Such as in Carthage during the sixth century.

⁴ Author's note: A horse untrained for battle was called "a horse that had not heard the bells."

⁵ Translator's note: Not to be confused with the Pien Ch'ing which is quarried from stone. They also number 16 and are hung in the same manner. The bells of the Pien Chung are of bronze casting. The playing of both the Pien Chung and the Pien Ch'ing has been kept alive in Korea.

CHAPTER VII

THE BELLFOUNDERS HEMONY

Francois (†1609-1667) and Pieter (1619-1680) Hemony were born in Levécourt, Belgium, which is in the province of Haut-Marne. Today this area is called le Bassigny but earlier it was the Dukedom of Lotharingen. In the sixteenth and early seventeenth centuries le Bassigny was an active bellfounding area. Annually on Ash Wednesday the itinerant bellfounders would leave their homes for far away places in order to apply their trade. Records show that they traveled as far as North Germany and Italy. At the beginning of the seventeenth century these skilled technicians of the bellfounding art returned home around the first of November. These bellfounders did not cast carillons but rather swinging bells and the tone quality of these bells was not always the most desirable.

In 1634 the Dukedom of Lotharingen was plagued with war, causing the Hemonys to leave the area of their birth.¹ Records show that in 1636

Francois, with the help of Josephus Michelin, cast his first bell in Germany.² He remained in Germany until around 1640, the year he married Josephus Michelin's daughter, Maria.

In order to fulfill a contract they received for the casting and delivering of a carillon to the Wine House Tower in Zutphen, Holland, they moved and established themselves there in 1642. After a thorough preparation they began casting the bells for this, their first carillon, in 1644-1646.

The innate difficulties of tuning a bell had, since 1550, been continuously and problematically solved. However, at this time the tuning of the bells was not the duty of the bellfounder but rather it was delegated to the carillonneur or another city musician. This readily caused problems. Since the detailed and necessary techniques for proper bell tuning were not known to the persons whose duty it was to tune these bells and musicians did not generally have the knowledge or understanding of the overtone structure of a bell, most tuning was unsatisfactory. It must also be noted that the

standard and appropriate bell profile had not yet been discovered. The high degree of excellence which the Hemonys reached in casting and tuning bells is largely due to the cooperation and counseling of Jhr. Jacob van Eijck (±1590-1657).

The blind Jhr. Jacob van Eijck, then city flutist and carillonneur of Utrecht, possessed such an extraordinary sense of hearing that he was capable of experimenting with the overtones of wine glasses. This may seem strange until it is realized that he was related to Christian Huygens. Others who were actively experimenting with and studying the overtone series were, to name a few, Mersenne, Isaac Beekman and René Descartes. Around 1200 Vincent van Beauvais had already identified three overtones of a bell.

Below is a list of the early carillons cast by the Hemony brothers during their stay in Zutphen. An (X) indicates an instrument no longer in existence. Since most Hemony carillons have been renovated by other foundries, these are indicated by B - Van Bergen, E - Eijsbouts, M - Michiels, and F - Petit & Fritsen.

	<u>City</u>	<u>Tower</u>	<u>Renewed</u>	<u>Original Date</u>
1.	Zutphen	Wine House	X	1644/46
2.	Deventer	St. Lebuinus	F	1647
3.	Enkhuisen	St. Pancras	E	1647/48/49
4.	's Hertogenbosch	City Hall	E	1649
5.	Utrecht	Nicolai	F	1649/50
6.	Arnhem	St. Eusebius	X	1650/51
7.	Utrecht	Jacobi	X	1651
8.	Amsterdam	Beurs (moved to Mint Tower in 1668)	F	1651
9.	Zaltbommel	Gasthuis	E	1654
10.	Culemborg	St. Barbara (partly destroyed)	E	1654/55
11.	Doesburg	Martini	X	1654/55
12.	Antwerp	Cathedral (City carillon)	E	1654/58
13.	Antwerp	Cathedral (Chapel carillon) (In 1960 a large part of this carillon was moved to Hoogstraten by Michiels)	M	1654/55
14.	Antwerp	St. Michiels Abbey	X	1655

In 1655 Francois Hemony received an invitation from the Mayor and City Council of Amsterdam to become the 'Bell and Canon Founder of Amsterdam'. During the Easter season of 1657 Francois moved his family and foundry to the Molenpad in Amsterdam. Francois and Maria Hemony had two children, Francois and Anna Margaretha. His brother, Pieter, remained a bachelor and, not moving with the family to Amsterdam, lived in Ghent until 1664.

The Amsterdam period was the most illustrious for Francois Hemony. The quality of his bells improved and he modified his bell profile, making it somewhat thicker and shorter.

Francois delivered a carillon to the Zuiderkerk in Amsterdam before he established his foundry in that city.

The carillons which he cast at his foundry in Amsterdam are:

(15.	Amsterdam	Zuiderkerk	B	1656)
16.	Amsterdam	Oude Kerk	E	1658

17.	Amsterdam	Westerkerk ³	E	1658
18.	Amersfoort	Onze Lieve Vrouwe Toren ⁴	E	1659/62/63
19.	Kampen	Nieuwe Toren	F	1659/62
20.	Delft	Nieuwe Kerk	E	1659/62
21.	Brielle	Catharinatoren	E	1660
22.	Rotterdam	Laurenstoren	E	1660
23.	Rotterdam	City Hall (moved to the Beurs in 1829)	X	1660
24.	Averbode	Abbey	X	1659-62
25.	Mainz	Liebfrauenstift	X	1660
26.	Haarlem	St. Bavo Kerk	E	1660-64
27.	Hamburg	Katharinenkirche (moved in 1663 to the St. Nikolaitoren)	X	1661-65
28.	Middelstum	St. Hippolytustoren	E	1661-62
29.	Brussels	Belfort	X	1662
30.	Hasselt (Ov.)	Stadstoren	X	1662
31.	Haarlem	Bakenessertoren	X	1662
32.	Groningen	Martinitoren	untouched	1662/63
33.	Groningen	Der Aa-kerk	X	1663
34.	Stockholm	St. Gertrud	X	1663/65

Due to the fact that every city is justifiably proud of its carillon, it is periodically renovated. Therefore, few original Hemony bells remain and only the carillon in the Martini Church in Groningen is yet untouched. A few of the better preserved carillons are in Amersfoort, Middelstum and the Mint Tower in Amsterdam.

While in Amsterdam Francois Hemony cast approximately 600 bells.

His wife, Maria, died in 1661, and his son, Francois, never showed any interest in bellfounding.

Taking apprenticeships in the Amsterdam foundry were Claude and Mammes Fremy (sons of a cousin in Winterswijk), Francois de la Paix, who in 1674 cast a carillon for Mons in Belgium, and Claes Noorden.

Francois Hemony was a highly respected citizen of Amsterdam. According to Huygens he was greatly skilled in both music and mathematics. From his letters we know that he was a very intelligent individual. His Dutch, although highly

perfected, always contained German words and expressions. The price for his carillons always remained the same, i.e., 17 to 24 stuivers (nickels) per pound of bell metal depending on the size of the carillon. The Hemonys were Roman Catholic and, therefore, Latin quotations from the Psalms often are found inscribed on their bells.

In 1664 Pieter moved to Amsterdam and joined his brother in the art of bellfounding. During the period in which Pieter worked in Ghent, late 1657 or early 1658 until 1664, he cast the following carillons:

35.	Tongerloo	Abbey	X	1658
36.	Ghent	Belfort	E	1659/60
37.	Ename	Abbey	X	1660
38.	Ghent	Beaudelo Abbey	X	1661

The carillon for the Belfont in Ghent was never officially accepted and a long legal battle ensued. Only the Reverend Wijckaert, who was well acquainted with the art of the carillon, sided with Pieter in insisting that the bells were quite

satisfactory. Despite the loud protests of Pieter and Reverend Wijckaert, the examining jury compelled Pieter to lower the tuning of the bourdon bell, the result of which satisfied no one.

While together in Amsterdam, Francois and Pieter cast only three more carillons:

- | | | | | |
|-----|------------|-------------------------------------|---|------|
| 39. | Utrecht | Dom Tower | E | 1664 |
| 40. | Amsterdam | City Hall (now the
Royal Palace) | E | 1664 |
| 41. | Maastricht | City Hall | E | 1668 |
- (This carillon was originally intended for Diest, Belgium, but was bought by the City of Maastricht in 1668.)

In 1663 Francois also began casting bronze sculptures. The statues atop the Royal Palace in Amsterdam were cast by Francois after being designed and made by Quellinus. Their names are: Prudence, Temperance, Alertness, Justice, Peace, and Atlas with the globe. The Hemony brothers were very busy casting guns and cannons, for in 1665 the Netherlands was, for the second time, at war with England. At the foundry they also cast mortars and pestles.

Francois Hemony died a very rich man
on May 24, 1667.⁵

Alone in Amsterdam, Pieter cast the
following carillons:

42.	Hulst	N. H. Kerk	X	1670
43.	Darmstadt	Residenzschloss	X	1670
44.	Diest	St. Sulpitius	E	1671
45.	Hoorn	Grote Kerk	X	1671

Hereafter he cast only a standard size
carillon, always keeping a few in stock:

		Cast In:		Bought In:	
46.	Oostende	City Hall	1671	1674	X
47.	Weesp	St. Laurens	1671	1676	E
48.	Enkhuizen	Dromedaris	1671/76	1676	E
49.	Mechlin	St. Rombouts	1674	1679	
50.	Gouda	St. Janskerk	1675/78	1678	E
51.	Leiden	City Hall	1677/78	1679	X

(Destroyed by fire in 1926)

After 1676 Pieter's health continuously
declined. During this time he had much corres-
pondence with Abbot Antoine de Loose of Ename.

Pieter died on February 17, 1680, leaving the carillon for Gouda unfinished.

The overall workmanship of the bells which Pieter cast was somewhat less precise and refined as compared with those cast by Francois.

Mammes Fremy succeeded Pieter as master bellfounder in Amsterdam but achieved little success. Claude Fremy soon succeeded his brother in that position. Only one carillon cast by Claude Fremy exists today. It was installed in the City Hall of Leeuwarden after being cast in 1686. When it was determined that the tower was too weak to hold the bells, they were taken down and stored in the cellar where they remain today, unfortunately hiding their beauty.

In 1689 Claude Fremy died. That same year his wife married Jan Albert de Grave, thus ending a partnership with Claes Noorden, the other apprentice of Francois Hemony.

After the Hemony era ended, there was a

short period of revival, of which the earlier carillon in Middelburg was a good example.

A very important and colorful epoch in the art of the carillon closed in ± 1712 with the death of Claes Noorden. Yet another reason for this is that all of the major cities in the Netherlands now had carillons.

It can safely be stated that the art of bellfounding falls into the following categories:

- I. Rise -- before the Hemony brothers until ± 1645.
- II. First flourishing period -- Hemony brothers until ± 1712.
- III. Decline -- 1715 until 1900.
- IV. Rejuvenation -- beginning of the 20th century with Taylor and the Reverend Simpson.
- V. Second flourishing period -- the second half of the 20th century.

¹ Translator's note: The Hemonys had been bellfounders for many generations, and Francois, being ten years older than Pieter, took his apprenticeship under his father. After leaving the Dukedom of Lotharingen the two brothers worked in Germany six to eight years.

² Translator's note: In Repelen, Germany.

³ Translator's note: It was these bells which, as Anne Frank wrote in her diary, made such a noise, yet were missed so much when they were silenced.

⁴ Translator's note: Often abbreviated to O.L.V. and when translated into English, means 'Our Lady of Love,' or perhaps better known as Notre Dame.

⁵ André Lehr: As Francois was buried in the Nieuwe Kerk in Amsterdam, the bells which he cast were rung three and a half hours to mark his passing.

CHAPTER VIII

OTHER BELLFOUNDERS

There were a number of carillons in the Netherlands before the Hemonys began their bell-founding, although these were not of the fine tone quality or workmanship as the Hemonys.

The oldest carillon in the Netherlands was cast in 1550/53/54 by Pieter van den Gheyn, and although no longer playable, is located in the City Hall of Zierikzee. It contains a diatonic scale plus a low b-flat.

In the Nieuwe Tower in Kampen there are four bells cast by Maria Johannes Gerhardus de Wou, commonly referred to as Geert van Wou. Two bells were cast in 1481, another in 1483, while the remaining bell is not dated. Another bell in the same tower was cast by Kiliaan Wegewaert of Kampen in 1627. All of these bells were returned by Hemony when he installed a carillon in the Kampen Tower in 1659/62.

Pieter van den Gheyn also cast some bells for Arnhemuiden in 1553. These have since been moved to the Rijksmuseum in Amsterdam.

A few early carillons are:

Edam	O. L. V. Tower	P. v. d. Gheyn	1561	
Heusden	City Hall	Thomas Both	1582	X
Monnikendam	City Hall	P. v. d. Gheyn	1596	
Sluis	City Hall	H. v. d. Gheyn	1601	X
Oudewater	St. Michiel	G. Both	1609 ¹	
St. Maartenskijk	N. H. Kerk	P. v. d. Gheyn	1614	
Tholen	City Hall	M. Burgerhuis	1627	

No significant carillons were cast during the 19th century.

Early in the 20th century the art of bell-founding flourished again when the John Taylor & Co. Bellfoundry, assisted by the tuning techniques rediscovered by Reverend Simpson, began casting tuned sets of bells. They were soon followed by the Gillett & Johnston Bellfoundry in Croydon. The Paccard Bellfoundry in Annecy-le-Vieux in southern France also joined this revival.

In the Netherlands the art of bellfounding was revived when the Petit & Fritsen Bellfoundry cast a two octave carillon for the 1925 Carillon Exhibition in 's Hertogenbosch. In 1932 a small carillon for the Jaarbeurs in Utrecht was cast by Van Bergen.

Before the above named carillons were cast, bellfoundries in other countries were installing carillons in the Netherlands. Most of these were lost in the destruction of the last war and others were plundered by the Nazis. A list of some of these carillons follows.

1905	Lochem	Paccard	29 bells	X
1911	Appingedam	Taylor	2 octaves	X
1913	Vlissingen	Taylor	33 bells	X
1914	Eindhoven	Taylor	2 octaves	X
1920	Rotterdam (City Hall)	Taylor	4 octaves in a-flat	X
1923	Bennebroek	Taylor	23 bells	X
1925	Zutphen (Wine House)	Taylor	36 bells	X
1925	Tilburg	Gillett & Johnston	35 bells	X

1925	's Hertogenbosch (St. Jan)	Gillett & Johnston	4 octaves	
1926	Almelo	Gillett & Johnston	38 bells	X
1927	Barneveld	Gillett & Johnston	2 octaves	
1929	Breda	Gillett & Johnston	4 octaves	X (partly)
1929	Zwolle	Taylor	$3\frac{1}{2}$ octaves	
1930	Oldenzaal	Gillett & Johnston	4 octaves	

For further information about these and the carillons after 1945 see Leen 't Hart's Overzicht Belaarden in Europa, (Survey of the Carillons in Europe). The following chapter also deals with carillons after 1945.

Below is a list of some of the largest bells in the world.

Moscow -- the Czar Kolokol located at the Kremlin weighs $\pm$ 200 tons and was cast in the years 1733-35 by Motorin. Its diameter is 6.60 meters and its height is 6.14 meters. While this bell was

being lifted from the casting pit, it fell
and an 11 ton piece broke from the bell.

The bell, having never rang, now rests
on a pedestal.

Peking -- a bell cast in 1403 weighing 53,000 kg.

Vienna -- St. Stephen. This bell, being cast in
1771 and weighing 15,700 kg., was
destroyed in 1945.

London -- in the St. Stephens tower at the
Parliament Houses is Big Ben, cast in
1858 by the Whitechapel Bellfoundry,
weighing 15,400 kg.

Paris -- the Notre Dame bell weighs 12,800 kg.
and was cast in 1680.

Delft -- the bourdon bell was cast by Van
Trier in 1566 and weighs 9,000 kg.

Utrecht -- the Salvator bell weighs 7,900 kg. and
was cast in 1506 by Van Wou.

Oldenzaal -- the largest bell weighs 7,200 kg., and
was cast in 1493 by Van Wou.

¹ Translator's note: This carillon is now
sitting on the floor of the church. It is hoped that
this instrument will be preserved.

CHAPTER IX

SOME FAMOUS BELLFOUNDERS

It is important to note that earlier a trade or profession often remained in a family for generations.

This is certainly true with the art of bellfounding.

Listed below are some of the more noteworthy bellfounders, followed by a number in parentheses indicating how many members of a family were active in the profession.

<u>Name</u>	<u>Dates</u>	<u>Place</u>
Butendic (6)	1440-1482	Utrecht
Jan and Willem Hoerken	1443-1471	's Hertogenbosch
Van Wou (5)	± 1450-1551	Nijmegen, Kampen 's Hertogenbosch
Waghevens (9)	1483-1574	Mechlin
Moer (6)	1500-1570	's Hertogenbosch
Tolhuis (3)	1527-1558	Arnhem, Nijmegen Utrecht
Wegewaert (6)	1542-1664	Deventer, The Hague Kampen, Enkhuizen

Van Trier (8) 1545-1697 Aken, Nijmegen

Huissen

Van Den Gheyn (3) 1561-1618 Mechlin

(Also, see the
v. d. Gheyns
after Hemony)

Both (4) 1593-1656 Utrecht

The foregoing list is pre-Hemony bellfounders,
while the following are the bellfounders after the
Hemony brothers.

Burgehuis 1617-1679 Middelburg

Petit since 1660 Someren, Aarle-Rixtel

Petit & Fritsen since 1815 Aarle-Rixtel

Petit since 1787 Gescher (Westphalia)

Petit & Edelbrock since 1843 Gescher (Westphalia)

M. and Cl. Fremy 1662-1683 Amsterdam

M. de Haze until 1740 Antwerp

Cl. Noorden until 1716 Amsterdam

Witlockx until 1730 Antwerp

J. A. de Grave until 1734 Amsterdam

Borchardt (2) 1732-1777 Groningen, Enkhuizen

P. v. d. Gheyn until 1740 Louvain

Andr. v. d. Gheyn¹ until 1790 Louvain

J. N. Derk	until 1764	Hoorn
G. Dumery	until 1784	Antwerp
Van Bergen	since 1795	Province of Groningen
Van Bergen	since 1850	Heiligerlee
Paccard	since 1796	Annecy-le-Vieux (France)
Taylor	since 1840	Loughborough (England)
Schilling	since 1826	Apolda (E. Germany)
Schilling	after last war	Heidelberg (W. Germany)
Gillett & Johnston	1877-1955	Croydon (England)
Michiels	1910-1962	Doornik (Belgium)
Eijsbouts	since 1947	Asten

The preceding list includes founders of swinging bells. Following is a list of some carillons from the above named founders. The same code for the foundries that did renovations will be used as in Chapters VII and VIII.

P. v. d. Gheyn	Amsterdam	1553	F	Rijksmuseum
P. v. d. Gheyn	Edam	1561	F	
P. v. d. Gheyn	Monnikendam	1614	F	

P. v. d. Gheyn	St. Maartensdijk	1614	E
G. Both	Oudewater	1609	unplayable
M. de Haze	The Hague	1686	E
M. de Haze	Gorinchem ²	1687	
M. de Haze	Alkmaar	1687/88	E
J. N. Derk	Leningrad (Russia)	1757	
Fremy	Riga (Russia)	1694	
Witlockx	Mafra (Portugal) ³	1730	
Le Vache	Mafra (Portugal)	1730	
P. and M. v. d. Gheyn	Nijmegen	1738	B (poor)
Andr. v. d. Gheyn	Schoonhoven	1771	E (fine)
Andr. v. d. Gheyn	Nijkerk	1777	E (fine)
Andr. v. d. Gheyn	Schiedam	1786	(very poor)
Gillett & Johnston	's Hertogenbosch	1925	
Gillett & Johnston	Barneveld	1927	
Gillett & Johnston	Oldenzaal	1930	
Taylor & Co.	Zwolle	1930	

In Belgium:

Michiels	Dendermonde	1949	renovations
Michiels	St. Niklaas	1955	renovations
Michiels	Edingen	1955	renovations
Michiels	Harelbeke	1960	

Michiels Mechlin 1953 (Busleyden Tower)

Michiels Meise 1949

Michiels Nieuwpoort⁴ 1953

In Germany:

Schilling in Frankfurt a/Main 1956/58

Heidelberg Kassel 1956

Heidelberg Hanover 1960

Heidelberg Beuel⁵ 1962

In France:

Paccard in Blois 1938

Annecy-le-Vieux Chalons s/Marne 1955

Annecy-le-Vieux Douai 1954

Annecy-le-Vieux Dunkirk 1962

Annecy-le-Vieux Saint-Amand-
les-Eaux 1949/50/58

Annecy-le-Vieux Tourcoing 1961

In England:

Taylor in Bournville 1906/25/34

Loughborough Cobh (Ireland) 1916/58

Loughborough Loughborough 1923

Gillett & Johnston Aberdeen 1952
(Scotland)

Mears & Stainbank Kilmarnok 1950
(Whitechapel) (Scotland)

For further information about these and other carillons, see Overzicht beiaarden in Europa by Leen 't Hart. Notice the number of carillons which came from Dutch foundries, and compare the number of carillons in the Netherlands to other European countries.

European founders have delivered a number of carillons outside Europe and below is a representative list. (tw = total weight)

Van Bergen -- Toronto, Canada, additions to the Gillett & Johnston carillon in the Hart House of the University of Toronto in 1953. Cleveland, Ohio (1953).

Eijsbouts⁶ -- Vila Formosa, Brazil (1951).

Petit & Fritsen⁷ -- Mexico City (1952), Sao Paulo, Brazil (1958), Tegucigalpa, Honduras (1959), and in the United States:

-- Bloomfield Hills, Michigan (Kirk-in-the-Hills), 77 bells, tw 63,970 lbs. (1960).

-- Cedar Falls, Iowa, 36 bells, tw 6,060 lbs.

-- Cleveland, Ohio, 46 bells, tw 26,230 lbs.

-- Green Bay, Wisconsin, 47 bells,

tw 26,430 lbs. (1957).

-- Grosse Pointe, Michigan, 47 bells,

tw 22,002 lbs.

-- Houston, Texas, 42 bells, tw 25,694 lbs.

-- Middletown, Ohio, 35 bells, tw 14,280 lbs.

-- Oklahoma City, Oklahoma, 42 bells,

tw 11,140 lbs.

-- Oklahoma City, Oklahoma, 42 bells,

tw 15,160 lbs.

-- San Antonio, Texas, 47 bells,

tw 18,434 lbs. (1953).

-- Santa Barbara, California, 61 bells,

tw 30,813 lbs.

-- Springfield, Illinois, 66 bells,

tw 68,690 lbs. (1961).

-- Bryan, Ohio, 49 bells, tw 7,986 lbs.

Paccard -- Montreal, Canada (1955/56);⁸ University

of California at Riverside (1966).

Gillett & Johnston -- Ottawa, Canada (1927); Culver,
Indiana (1951); Chicago, Illinois⁹ (1930/32);
New York City, New York (1924).¹⁰

Taylor & Co. -- Ames, Iowa (1899/1929/56); National
Cathedral in Washington, D. C. (1963); Lake
Wales, Florida (1927); Ann Arbor, Michigan
(1936).¹¹

In Arlington, Virginia, near Washington, D. C.,
is the Netherlands Carillon. The money for this
carillon was raised in the Netherlands and presented
to the peoples of the United States of America in
appreciation for their help during and after World
War II. Each of the three Dutch bellfoundries cast a
certain number of bells. It is not known today which
foundry cast which bells. The sound could not be
worse, particularly in the upper octaves. Also, the
tuning is far from satisfactory.

¹ Author's note: Brother of Matthias van den
Gheyn.

² Author's note: Now located in a shopping
center and playable only automatically. Petit &
Fritsen cast a new and large carillon for Gorinchem
as a replacement.

³ Author's note: Both the carillon cast by Witlockx and the one cast by le Vache are located in the Royal Palace in Mafra, Portugal. The Witlockx carillon is in the North Tower and the Le Vache carillon is in the South Tower.

⁴ Author's note: This carillon in Nieuwpoort, Belgium, is tuned in the Pythagorean temperament. Being an experiment it has 17 notes and, hence 17 bells per octave. The console is so constructed as to have two rows of black keys, totalling three rows of manual keys. The lowest row contains the normal white keys, a, b, c, d, e, f, g, a, b, c, etc. The middle row contains c-sharp, e-flat, f-sharp, g-sharp, b-flat, etc., and the highest row contains d-flat, d-sharp, g-flat, a-flat, a-sharp, etc. The carillon contains a total of 67 bells.

⁵ Author's note: Beuel is located near Bonn and its carillon is probably the largest in Germany.

⁶ Translator's note: The Eijsbouts Foundry recently installed two beautiful carillons at Indiana University in Bloomington, Indiana. Both the large Arthur R. Metz Memorial Carillon and the smaller practice instrument atop the School of Music were dedicated on October 22, 1971 with Arie Abbenes performing.

⁷ Translator's note: The Petit & Fritsen Foundry installed a large new carillon at The Brownell Memorial Park in Morgan City, Louisiana, dedicated on November 21, 1971.

⁸ Translator's note: Earlier, the Paccard Foundry installed a beautiful carillon at The Washington Memorial Chapel in Valley Forge, Pennsylvania.

⁹ Author's note: The bourdon bell sounds a c-sharp and weighs approximately 18-1/2 tons.

10 Author's note: Now located at the Riverside Church in New York City, this carillon is the largest in the world by weight, having a bourdon bell weighing approximately 20 tons. This carillon was enlarged to 74 bells by Van Bergen.

11 Translator's note: The Taylor carillons in the Bok Singing Tower in Lake Wales, Florida, at The University of Michigan in Ann Arbor, and at the National Cathedral in Washington, D. C., are identical in range and size, and have been called the three sister carillons in the United States. Each carillon has a bourdon bell weighing approximately 12 tons and contains 53 bells, giving a range of 4-1/2 octaves.

CHAPTER X

THE DEVELOPMENT OF THE BELL PROFILE

Early cast bells had profiles that were evenly thick and had a vague sound-bow. Until the 11th century they had a shape much like a beehive.

During the 12th century the sound-bow became noticeably thicker and the bells taller and more conical. The shoulders remained round causing the bells to have a form like a sugar loaf, sometimes referred to as being like a pointed hood. From these shapes the Gothic profile developed.

During the 13th and 14th centuries the shoulders became more square and the sound-bow still more distinctive. Bells continued to be comparatively tall and some bells still had noticeably conical shoulders, being narrower than what is common today.

Important improvements were made during the 16th century. For example, the basic

measurements of a bell, the ratio of its height to the diameter of its sound-bow, was discovered. This ratio, an important function of the Gothic profile, is exemplified in the beautiful bells cast by Geert van Wou, who was busy casting bells in Kampen from about 1480 until 1527.

During the 17th century the Hemony brothers were active casting their uniquely beautiful bells in the Netherlands. As they worked, from 1642 until 1678, they amended the Gothic profile, which even today is being experimented with in order to find the best bell proportions. The Hemony profile is a more balanced shape having a less prominent sound-bow. During their period in Zutphen the Hemony's cast bells having a taller profile, while during their Amsterdam period they cast bells having what is known today as the Hemony profile, which is somewhat shorter and thicker than the Gothic profile.

Generally, it can be stated that three bell profiles have been developed.

1) The Gothic or German profile is the oldest. The Germans tend to copy the profile of the Maria Gloriosa bell which was cast in 1497 by Geert van Wou and still hangs in the Cathedral of Erfurt. It weighs approximately 11,350 kg. and has a diameter of 258 cm. and sounds an e. The Maria Gloriosa bell was copied from an earlier bell cast by van Wou named the Gloriosa bell.

2) The Hemony profile is shorter and thicker (hence heavier) than the Gothic profile, and has a particularly balanced shape.

3) The English profile has a somewhat rounder shape and a slightly less pronounced sound-bow.

CHAPTER XI

IMPORTANT MEASUREMENTS OF A BELL

The most important measurement of a bell is that of the diameter (D) of the sound-bow. The height of a bell, without its crown, is approximately 0.8 D. For example, if the diameter of a bell is 100 cm., its height would be approximately 80 cm. The height of a crown is about 0.2 to 0.25 D.

The diameter of the shoulder, more accurately called the upper interior diameter, is approximately 0.5 D. A bell having a pitch an octave higher would have a diameter of $1/2$ D, just as a bell having a pitch an octave lower would have a diameter of 2 D. However, as bells become smaller in the upper compass of the carillon,¹ the ratio of the diminishing diameter and weight becomes proportionally less.²

The weight of a bell doubles by descending major thirds. For example, a c^1 bell might weigh 2200 kg. and the e^1 bell, being

a major third above, might weigh 1100 kg.

This ratio does not always hold true, especially for small bells. The weight of a bell can roughly be assessed by using the following formula:

$$M \text{ (mass)} = 630 \times D^3 \quad (D \text{ in meters and } M \text{ in kg.})$$

Using a c^2 bell with a D of 76 cm. as an example

$$\text{we can apply the formula: } M = 630 \times (0.76)^3,$$

$$\text{hence, } M = 630 \times 0.438976 = \pm 276.5 \text{ kg.}$$

The diameter of a bell can also be roughly calculated if the pitch is known. The pitch of a bell is the product of the frequency (n) and the diameter (D). For bronze the formula is $n \div D = 200$, again with D in meters. For example, a c^2 bell has a frequency of 264 Hz. Therefore, $264 \div D = 200$ or $200 \div 264 = 0.76 \text{ m.}$

The weight of the clapper hung in a swinging bell is 3% to 5% the weight of the bell. This is not true, however, for clappers in carillon bells because heavier bells have proportionally lighter clappers often being only 1% of the bell weight. Light bells have comparatively heavy clappers, sometimes up to 10% the weight of the bell. Heavy clappers tend to

bring out the lower harmonics, particularly the hum-tone, while light clappers tend to bring out the higher harmonics.

Listed below are a few examples of clapper weights:

<u>Bell Pitch</u>	<u>Weight in kg.</u>	<u>Swinging Clapper</u>	<u>Carillon Clapper</u>	<u>Hour Strike Hammer</u>
c ¹	2200 to 2300	65 to 70 kg.	app. 30 kg.	app. 40 kg.
c ²	250 to 260	9 to 11 kg.	5 to 6 kg.	app. 7 kg.
c ³	50 to 60	4 to 5 kg.	2 to 2½ kg.	----

¹ Author's note: Beginning at approximately f².

² Translator's note: Although this is not a new discovery, it has recently been taken to an extreme which allows for the casting of small bells which are relatively heavy and having a thick profile. Although these bells are beautifully sharp, clear and resonant, criticism has been forthcoming in that the bell shape has been lost.

CHAPTER XII

ADORNMENTS AND INSCRIPTIONS

Early bells did not have inscriptions although some of the later bells having the beehive shape had crude adornments.

The bells cast by Geert van Wou have adornments and inscriptions in a very severe Gothic style. The Hemonys, while strongly influenced by the Renaissance style, also used many Baroque figurines and employed Latin inscriptions.

During the 18th and 19th centuries bells were often adorned to excess, which, although beautiful to behold, was dangerous to the purity of tone.

After 1920 the trend was towards austerity. German foundries are particularly conservative in their approach to ornamentation, but, within the last few years, have adorned their

bells in a contemporary and particularly beautiful style. Some of the large bells cast by the late F.W. Schilling of Heidelberg are a good example.¹

¹ Translator's note: A picture of a beautiful Schilling bell is on the cover of this book.

CHAPTER XIII

SWINGING BELLS

There are three basic ways of hanging a swinging bell, other than the style and mechanism devised by the British for their change-ringing art.

1) The bell is hung as a pendulum, which means the yoke is a straight axis, causing the clapper to 'fly'.

2) The bell is hung on a crank yoke causing the axis to be low around the shoulder of the bell and the clapper will 'fall' against the bell.

3) The bell is hung with the same crank yoke but the clapper is counterbalanced. This method was invented by the Petit & Fritsen Foundry.

When a bell is hung as a pendulum, its axis lies parallel and equal with the top of the crown. The bell, after swinging up to a 90° angle, affects a slight pause and then returns. The clapper, having its axis at the head of the bell, will 'fly' up against the inner side striking the bell at the highest point

of its swing. The result is a supple clapper stroke and a beautiful formation of harmonics.¹

The second method of hanging a swinging bell has its axis at approximately the height of the shoulder of the bell. There is considerably less reaction force transferred to the tower but the sound of the bell is weaker. Less space is required in the tower for the circumference of the swing is not as great as when the bell has a straight yoke. Also, the bell does not swing as high in an arc and the bell swings and therefore rings slower. The results are a rougher formation of the harmonics and the sound does not travel as far. The bell collides with the clapper as the clapper is suspended almost vertically while slightly pausing at the apex of its swing.

With the third method the axis is also at the height of the shoulder of the bell. However, the axis of the clapper is considerably lower and is so constructed as to be out-of-balance above its axis. The overall results are a formation of harmonics like a bell hung as a pendulum but

causing considerably less reaction forces to be transferred to the tower. This is an ideal solution for towers having little space for bells and for towers which were not built strong enough to withstand the forces generated by a bell hung on a straight yoke.²

By using the following formulas the reaction forces of swinging bells can be roughly calculated.

1) For a bell hung as a pendulum on a straight yoke:

- a) horizontal forces,
maximum $1.55 \times$ bell weight
- b) vertical forces,
maximum $3.1 \times$ bell weight

2) For a bell hung on a crank yoke:

- a) horizontal forces are
negligible
- b) vertical forces,
maximum $1.25 \times$ bell weight

It can be seen that there are large differences of reaction forces generated by these methods of hanging swinging bells, and full consideration must be given to these forces before a bell is installed in a tower.

Bells having the same pitch do not necessarily have the same weight. It is obvious that a bell having a heavier profile will be more resonant and sonorous than a bell having a lighter profile, for more bronze is used in a bell with a heavy profile. Bells with a light profile tend to produce a thin, shallow and weak sound while bells cast with a too heavy profile will sound dampened and cold, for it is difficult to bring such a large mass of metal into vibration.

Following is a list of the approximate weights of three different profiles which sound the same note. The average between the heavy and the light profile, commonly called the normal profile, is usually preferred.

Note	<u>Heavy Profile</u>		<u>Normal Profile</u>		<u>Light Profile</u>	
	<u>Weight</u> <u>in kg.</u>	<u>Diameter</u> <u>in cm.</u>	<u>Weight</u> <u>in kg.</u>	<u>Diameter</u> <u>in cm.</u>	<u>Weight</u> <u>in kg.</u>	<u>Diameter</u> <u>in cm.</u>
c ¹	2755	159	2300	156	1790	147
d ¹	2000	140	1600	138	1300	129
e ¹	1335	126	1100	123	900	114
f ¹	1100	117	930	115	750	109
g ¹	775	104	660	102	540	95
a ¹	540	92	450	90	380	83
b ¹	375	81	310	80	230	73
c ²	300	76	269	75	190	69

The list below illustrates the wall thickness of the Hemony profile. Actual Hemony bells were used for these measurements.

<u>Note</u>	<u>Approximate Wall Thickness</u>	<u>Approximate Weight</u>
c ¹	50 mm.	2300 kg.
c ²	25 mm.	290 kg.
c ³	15 mm.	
c ⁴	10 mm.	

It is interesting to note that as the pitch becomes higher, the walls become proportionally thicker.

¹ Translator's note: This method of hanging a bell is ideal for the sound of the bell. However, considerable and possible damaging reactionary forces are transferred to the tower.

² Translator's note: It would appear that another ideal suspending of a swinging bell is to hang the bell on a straight yoke with counterbalance weights above the yoke. The clapper would 'fly' and the sound of the bell would be full and rich. However, more space would be required and the tower would have to be strong enough to hold the added weight.

CHAPTER XIV

COMPOSITION OF BELL BRONZE

The normal composition of bell bronze is 78% copper and 22% tin. As a rule, smaller bells have a higher percentage of tin, up to 25%, while larger bells are given a higher percentage of copper, up to 80%.

Since it is impractical to buy pure copper and tin, certain adulterants are inevitable, and these must be anticipated and tolerated. Lead is tolerated up to 1%, for more would harm the tone of the bell. Zinc, more difficult to eliminate, is more harmful to the tone, and is allowed only to 2%. Other alloys such as iron and nickel can also be anticipated. Only 3% of these adulterants is tolerated in a bell.

The melting point of bronze is approximately 900° C. and the temperature at which a bell is cast is about 1100° C. The fracture sheet of good bronze is grey white to white and, as on cast ingots, is quite

fragile. As time passes, a thin covering called patina appears on the bells and is a result of copper oxidation. The patina, a natural phenomenon, is further aggravated by air pollution and the corrosion lessens the total presence of bell bronze. After years of exposure it affects the tone of the bell. A heavy carillon in c, for example, loses approximately 300 grams of metal per year through oxidation. As air pollution increases, more bell bronze will be lost.¹

Much experimentation has been conducted in the search for the correct composition of bell bronze. Bells have also been made of porcelain and iron. Iron bells, made by Bochumer Verein at the Gusztahlfabrikation (Steel Foundry) in Bochum, Germany, are cast considerably larger in order to give the same pitch as a bronze bell. Corrosion is also a major problem. The tone of a steel bell is dark, cold, and rigid and because of a weaker strike-note, it does not resonate like a bronze bell.

Below is a comparison of weights between
iron and bronze bells.

Note

f bronze = 930 kg. diameter 115 cm.

f iron = 1060 kg. diameter 138 cm.

¹ Translator's note: The Amsterdam Carillon Commission has recently issued a report about the bells in Amsterdam in which they expressed grave concern for the future. The air pollution in Amsterdam has increased to such a point that they can foresee the day when the bells will have to be removed in order to be preserved.

CHAPTER XV

SURVEY OF CARILLON CONSTRUCTION

- A. Bellchamber
- B. Frame and Suspension
- C. Trackers and Transmission Systems
- D. Console

A. Bellchamber

The bellchamber should be large enough to allow the bells to be favorably suspended, preferably in whole-tone series, and at the same time allow enough space for the playing cabin.

There are many possible solutions to the question of necessary space in the bellchamber, but as a rule, the minimum required space for a light carillon based on c^2 is 3 X 3 meters of floor space and 4 to 4-1/2 meters in height. For a heavy carillon based on c^1 , 4 X 4 meters of floor space and about 7 meters in height is required. When the playing cabin is not included in this space, 16

cubic meters may be subtracted from the foregoing measurements.

Ideally, the bellchamber should be completely open, but a minimum of 25% is sometimes acceptable.

The mouth of the lowest hanging bell must be adequately above the bottom of the window openings so that the sound of the bell is not hindered. Due to the large amount of sound generated by the playing of the carillon, it is recommended that some absorbant material be installed on the walls of the bellchamber. This is particularly true of a semi-closed bellchamber in a tower constructed of concrete. Experimenting with absorbant materials for each instrument is the best solution. Wooden walls tend to be unsatisfactory because the wood strengthens the lower tones of a bell while absorbing the higher overtones. It is often desirable to install reverberation boards above the carillon if it is situated in a tall tower. Reverberation boards above swinging bells must be at least 1 to 1-1/2 times the bell height

above the axis of the yoke.

If possible, the openings of the bellchamber should be covered with a fine bronze wire mesh in order to keep our fine-feathered friends out of the bellchamber.

When louvers are present, it is advantageous to have most with a shallow incline and a few with a steep incline.

In drafting plans for a carillon, it must be remembered that all parts will be exposed to the elements. Provisions for eventual repairs must, therefore, be made. All ladders, gangplanks, and climbing irons must be securely fastened to the bell frame. It is recommended that an efficient lighting system be installed in the bellchamber since there is always the possibility of a broken wire during an evening concert and a lighting system would facilitate a quick and safe repair. During an evening concert the sound of the carillon seems to radiate from the tower and a judicious placing of lights on the bellchamber floor gives a beautiful effect.

The most desirable height for a heavy carillon is generally 50 to 70 meters above the ground. Lighter carillons are more effectively installed in short towers; however, some carillons are placed at the roof level of surrounding buildings.

B. Frame and Suspension

Listed below are some of the most popular constructions of bell frames.

1) Bell frame constructed entirely of metal.

Certain considerations must be given when metal frames are used. First, adequate insulation must be installed between the bell and the frame so that vibration transfer does not occur. Each bell must be totally isolated. Second, an efficient full bath galvanizing process must be used on all structural parts. About a year after its installation the bell frame should once again be painted with liquid metallic zinc so that it will exude around all parts. As a rule nuts and bolts are not galvanized; they are painted or protected in another way.

2) Bell frame constructed of a combination of metal and wood. The structural components are metal while the beams holding the bells are wood, preferably teak or other tropical hardwoods.¹

3) Bell frame constructed entirely of wood.

Again the tropical hardwoods such as teak are best.

Galvanizing Process:²

The application of the layer of zinc may be accomplished by several methods.

1) Full bath galvanizing (also called Fire Galvanizing) occurs when the steel is lowered into a bath of molten zinc, making an alloy with the iron on the surface. The thickness of this zinc-iron alloy depends on the temperature of the zinc bath and the submersion time.

2) Electroplating galvanizing is a process in which an electric current is passed through an aqueous solution of zinc salts which dissociates into ions. Then the solution is deposited on the steel.

3) Sherardizing occurs when the steel is placed in zinc dust and, when heated to a high temperature, vaporizes and forms the zinc-iron alloy on the surface of the steel. It is possible to use this method for nuts and bolts.

4) Spray Coating galvanizing, often called Plasma Spray, occurs when molten zinc wire is shot through a spray gun onto the steel, covering it with minute drops of zinc.

5) Liquid Metal galvanizing is accomplished when a paint with a high percentage of metallic zinc dust is applied to the steel. This is considered to be a poor method for galvanizing bell frames since more protection is needed.

The etchings caused by the formation of the zinc-iron alloy on the steel is noticeable when the Full Bath galvanizing process is used. This method is highly recommended. The other methods tend to cover only the surface like paint.

The bell frame must be totally isolated from

the floor and walls. Vibration transfer is especially noticeable in concrete towers and is more than an annoyance since it can cause structural damage. The bell frame must be strong enough to suspend and hold the bells absolutely stationary. The bell must remain immovable even with the force of the clapper striking it. Torsion must not be allowed in the suspending beams.

The metal frame must be adequately connected to the lightning conductors in the tower. When wooden suspension beams are not used and the bells are isolated from the metal beams, each bell should also be connected to lightning conductors.

Once a year the bell frame, suspension beams, and the bell supports should be checked for rust, loose nuts and bolts. The clapper hangings should also be inspected, since the inside of a bell is often moist.

The fanning of a cool wind causes moisture to condense in the stagnant air inside the bell and forms carbonic acid. Because of this possibility, steel clapper hangings, having a metallic contact with the bell, often quickly rust. This chemical reaction

occurs whenever moisture is present on a steel-bronze contact. To prevent this all metal parts (except the bells, of course) should be galvanized with the Full Bath process.

If there are no skilled carillon technicians in the area, it is recommended that a contract be signed with a bellfounder's representative in order to insure proper maintenance of the instrument.³

It is desirable to have the bells hung in whole-tone series, although other ways are possible.

1) The large bells (for example, c¹ to f-sharp¹) are often situated under the playing cabin and the remaining bells above the cabin with the smallest bells close to its roof. This distribution of bells can be seen in the St. Laurens Tower in Rotterdam and also in Gorinchem.

2) The largest bells are placed near the top of the bellchamber, graduating to the smallest bells close to the roof of the playing cabin. This can be seen in the Polder Tower in Emmeloord.

3) When the larger bells are also used as swinging bells, they are often located in another chamber below the bellchamber housing the carillon, as seen in the St. Laurens Tower in Rotterdam.

It is necessary to have a sound system installed so that the carillonneur may hear these bells.

4) The large bells are often housed around the cabin with the smaller bells above. Often this causes a less than satisfactory control of the large bells, as can be seen in Amersfoort.

5) All of the bells above the playing cabin does not always offer the best control from the console; however, this arrangement is favorable for the sound of the carillon because the smallest bells are near the ceiling of the bellchamber.

6) The bells could be placed in the window openings of the bellchamber as seen at the Nieuwe Kerk in Delft. This is fine for chromatic and polyphonic music, but for the fusion of tremolos and broken chords, etc., it is far from ideal, especially if the tower is low. All too often the

wire trackers are too long for proper control from the console, as can be noticed when playing the carillon in Delft.

7) The bells may be hung in a circle as in the St. Jacobs Tower in The Hague and the Royal Palace in Amsterdam. This is a possible solution to the problem of limited space in the bellchamber.

Since short tracker lengths are required for proper strike control on the console, obviously the best arrangement for hanging the bells is the first, which has the large bells under the cabin.

C. Trackers and Transmission Systems

The wire used for trackers must not have any resiliency nor be so brittle that they easily break. Straight wire trackers tend to break primarily at joints or where they are curved into an 'eye'. Rust-proofed steel and silicon-bronze wires are used often and seem to be quite satisfactory. Tracker wire must never be wound in a bundle but rather

delivered and stored as straight pieces. When installing the transmission system of a carillon, care should be taken that the wire is not twisted or bent. An 'eye' joint can easily be made by one bend of the wire and the pinching of a copper sheath around it to hold it secure. The sheaths are simply made from copper tubing such as is available at many auto supply stores.



When a long tracker is necessary, it is best to have as few joints as possible. Trackers with the least joints are the most supple. It is recommended that tracker guides be installed every 1 to 1-1/2 meters to prevent a sideways motion of the wires. The trackers must have enough space to move freely through the guides and yet not cause distracting noise. All unnecessary friction and torsion must be eliminated from the trackers in order to have a supple action from the console.

Transmission Systems

1) Broek system

2) Transmission Bar system (often called tuimelaar system)

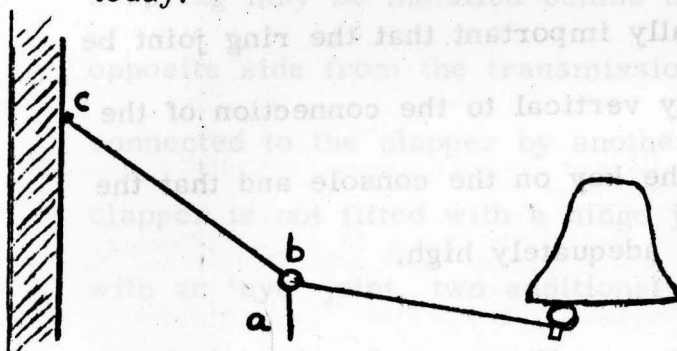
3) Easy system (Eijsbouts)

4) Direct Transmission system
(Petit & Fritsen)

5) Balanced transmission system
(Petit & Fritsen)

1) The Broek system⁴ is rarely used today.

An indirect usage of this system can be seen in the carillon of the City Hall of 's Hertogenbosch. Often the Broek system was used for large bells under or around the playing cabin although with the perfection of the Direct Transmission system this is not necessary today.



a. wire tracker
connected to
the console.

b. ring joint

c. stationary point

(See Timmermans,
page 157.)

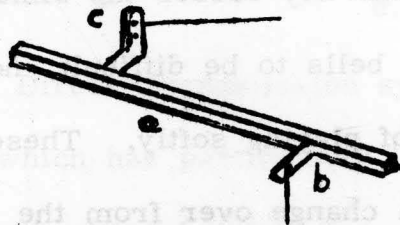
The disadvantages of this system are that the trackers tend to sway considerably and all too often snag on others. Due to the openings of the bellchamber it is often difficult to locate the desired fixed point. This system also causes a labyrinth of wires in the bellchamber making repairs quite difficult.

One of the most important advantages is that, theoretically, there is no friction. However, this does not compensate for the fact that, due to the swaying of the wire trackers, a good tremolo is very difficult to perform. It has often been said of the Broek system that the carillonneur does not have the clapper "in his hand".

It is vitally important that the ring joint be positioned directly vertical to the connection of the wire tracker to the key on the console and that the fixed point (c) be adequately high.

2) The Transmission Bar system can only be used if the bells are hung in rows. The transmission bar, often called tumbler or tuimelaar in

Dutch, consists of an axle (a) which is located between the bell and the console, a horizontal arm (b) and a vertical arm (c) positioned opposite the clapper. The wire tracker to the console is connected to the horizontal arm (b) while the tracker to the clapper is attached to the vertical arm (c). Counterweights are often placed behind the vertical arm (c) for heavy clappers. This placing causes the least torque on the transmission bar.

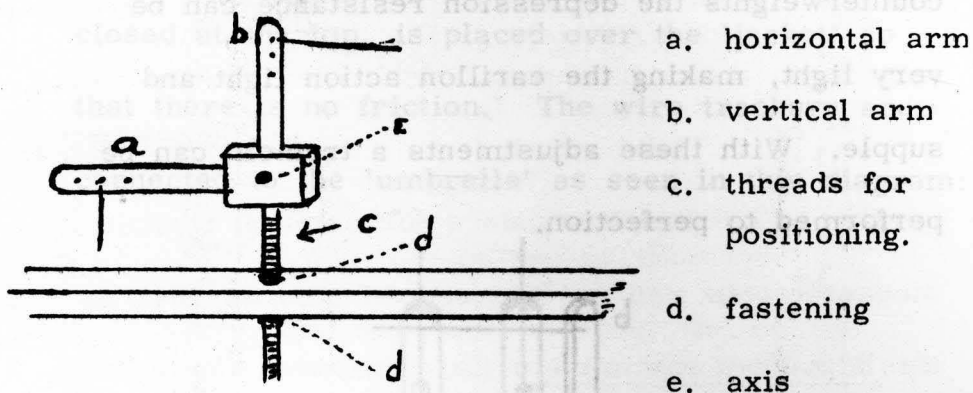


Since the clappers of small bells are often too light to quickly return to their resting position, a spring may be installed behind the clapper on the opposite side from the transmission bar and connected to the clapper by another tracker. If a clapper is not fitted with a hinge joint but rather with an 'eye' joint, two additional wires must be attached to the clapper. These wires extend sideways from the clapper and prevent the clapper from making a sideways motion. These wires steady the clapper in its travel and therefore must not be tight.

3) The Easy system has proved less than ideal because the tumbler and the clapper form one unit causing the action to be less controllable. The key encounters more resistance at the beginning of the depression and tends to 'fall away' as the stroke continues. The clapper-ball is located at the end of an arm of the tumbler, therefore there is no clapper attached to the bell. This system is applicable only to small bells. The differences in the depression resistance of the key causes the simultaneous ringing of two bells to be difficult, not to mention the difficulty of playing softly. These drawbacks alone justify a change over from the Easy system to a more reliable Transmission Bar system. A system of springs must also be installed for the quick return of the key.

4) The Direct Transmission system is most practical when the bells are hung in regular rows. This system resembles the normal Transmission Bar system except that the axle is omitted. The end of the horizontal arm is again positioned directly vertical to the connection of the wire tracker to the

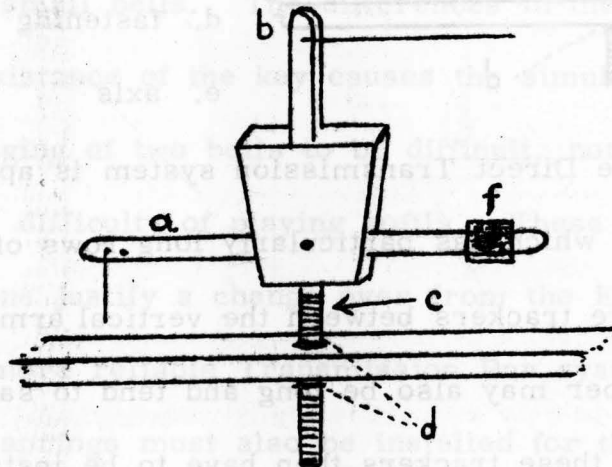
key and the vertical arm is connected directly to the clapper by means of another tracker. The tumbler unit can be turned in any direction to face a bell and can be placed at any height.



If the Direct Transmission system is applied to a carillon which has particularly long rows of bells, the wire trackers between the vertical arm and the clapper may also be long and tend to sag. Supports for these trackers then have to be installed but this also increases the friction.

5) The Balanced Transmission system is of the same principle as the Direct Transmission system. The major difference is that springs, which tend to wear out, are substituted with counterweights on an arm extending the opposite direction from the horizontal arm (f). These lead weights

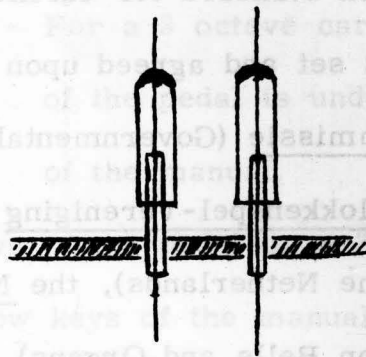
are easily adjustable. With this system every key can be adjusted to have the same approximate depression resistance, making the carillon very comfortable to play. By properly placing the counterweights the depression resistance can be very light, making the carillon action light and supple. With these adjustments a tremolo can be performed to perfection.



Transit of the wire trackers.

It is obvious that the tracker between the console and the transmission system must pass through the roof of the playing cabin. By using a 'protection rack', sometimes called a 'dam' but more often referred to as 'umbrella hoods', rain and other weather conditions may be kept out of the playing cabin.

Little copper 'jackets' are constructed through the roof of the cabin and are positioned directly above the connection of the trackers to the keys. The 'umbrella hood', which is wider and closed at the top, is placed over the 'jacket' so that there is no friction. The wire trackers are connected to the 'umbrella' as seen in this diagram:



Suspending the clapper.

Clappers may be hung by several different methods:

- 1) A clapper hooked to an 'eye' inside the bell was very popular for early carillons.

Sideways supporting wires must then be installed to prevent the clapper from a sideways motion.

- 2) The clapper could be attached by using a hinge which occasionally has to be greased.

3) A hinge of leather or a nylon composition is always very supple, but an annual inspection is necessary because of wear.⁵ Plastic should never be used.

D. Console

The Dutch standard for carillon console measurements was set and agreed upon in 1949 by the Rijksadviescommissie (Governmental Committee), the Nederlandse Klokkenspel-Vereniging (Guild of Carillonneurs in the Netherlands), the N.K.O. (Catholic Council on Bells and Organs), and the Dutch bellfounders. The Dutch standard is used throughout Europe and other parts of the world.⁶

The Dutch standard is closely aligned with the Mechlin standard as set by Jef Denijn. The major difference is that the depression depth of all keys is the same for the Dutch standard while in the Mechlin standard the depression depth of the white keys is more than the black keys, making the simultaneous playing of a white and black key very difficult.

Some specific measurements of the Dutch standard are:

Position of the pedalboard in relation to the keyboard --

-- For a 4 octave carillon the c of the pedal is under the c¹ of the manual.

-- For a 3 octave carillon the c¹ of the pedal is under the c¹ of the manual.

The low keys of the pedal on a 3 octave carillon lie under the low keys of the manual with both the manual keys and the pedals playing the same bell. For a 4 octave carillon the lowest bells are only playable on the pedal: for example, the low c to f-sharp. The keyboard begins with g.

The range of the pedalboard is 1-1/2 octaves, from c to and including g¹.

The measurements for the key protrusion from the comb at the front of the console are:

- a. Black keys of the manual: 75 mm.
- b. White keys of the manual: 135 mm.
- c. Black keys of the pedal: 100 mm.
- d. White keys of the pedal: 170 mm.

The length of the keys inside the frame of the console is 440 mm. This is measured from the center of the axis at the back of the key to the center of the comb, i.e., where the protrusion that is struck begins.

The depth of depression for all keys is 60 mm.

Measured from the upperside of the keys and pedals, the distance between the keyboard and the pedalboard is 72 cm. The Eijsbouts Bellfoundry uses this measurement while the Petit & Fritsen Bellfoundry uses 78 cm. which is somewhat more comfortable for long-legged carillonneurs. The distance between the pedal and keyboard on the American standard, adopted in 1967, is 31 inches or 78.74 cm.

The distance between the white and black keys for both the keyboard and pedalboard is 100 mm.

The horizontal distance between the centers of the keys on the keyboard is 46 mm. while the distance between the centers of the white and black keys of the pedalboard is 42-1/2 mm.

The size of the music rack was not decided but it is recommended that it be at least one meter wide and 40 cm. high. It would be ideal if it were the width of the console and, at the same time, adjustable.

Apart from these measurements there are some striking differences between the Dutch and the American standards. For one, the American standard was determined more scientifically.

The range of the pedalboard on the American standard is two octaves, having the b of the pedal directly under the d¹ of the keyboard. The distance between the centers of the manual keys on the keyboard is 51 mm., and the depression depth of all keys

is approximately 5.1 cm. The distance between the centers of both the white and black pedal keys is 44-1/2 mm. When compared with the Dutch standard measurements there is considerable difference.

The connection of the wire trackers to the keys must be very supple. A good solution is to mount a small revolving axle on or in the key, to which the turnbuckle is connected. This axle will accept all pivotal pressures and there will be no binding or movement at the tracker connection.

It must always be possible to adjust the carillon with a fine accuracy. The length of the wire tracker between the key and the clapper is adjusted by using a turnbuckle. Each bellfounder has his own style of turnbuckles, and the I. T. Verdin Company in Cincinnati, Ohio, has a very sophisticated unit which works very well. Earlier the Eijsbouts Bellfoundry used a screw-eye connection which necessitated that the tracker be unhooked before it could be adjusted. Currently they are

using an 'eye' joint connected to a turnable unit above the peg which fastens the tracker to the key.

The Petit & Fritsen Bellfoundry has designed a tension turnbuckle which allows for fine adjustment, and once adjusted, secures the tracker at that length. This method is preferred.

The carillon bench must be adjustable, preferably not with predetermined step positions.

The Petit & Fritsen Bellfoundry has designed an outstanding bench which satisfies this demand.

The construction of the bench used by the Eijsbouts Bellfoundry is somewhat less satisfactory, for the bench is adjustable only to preset positions and, as the carillonneur moves the bench to be comfortable, he is often sitting in a poor position for playing, as several of the students who practice at the Belgium Monument have painfully discovered.

The manual keys should be of ash and the pedals of oak. It is recommended that the playing surfaces of the wooden pedals be covered with leather or hard rubber to prevent wear.⁸

The actual console may have a wooden or metal

frame. In the event the console frame is metal, some form of rust-proofing should be applied.

The console must be securely fastened to the floor of the playing cabin and there must be ample room around the console for eventual repairs on the sides and back of the console. The playing cabin must also allow enough space so that the bench in front of the console may be moved back to accommodate the tallest carillonneur.

It is desirable that at least three sides of the playing cabin have windows or shutters so that the carillonneur may accurately hear his performance. This is absolutely necessary for proper control. When it is not possible to have windows, another solution is to have a trap door installed in the ceiling. This should be so constructed that it may be opened in several different directions to shield against rain. There are several trap door units on the market today which serve this purpose very well.

A noiseless console is still a dream

although there are several improvements which can be accomplished to make the action quieter. Plastic or hard rubber could be installed in the comb above and below the key and Teflon may be used on the sides of the comb to decrease friction and lateral motion. Care must be given that any sound-proofing material placed under the keys is strong enough to withstand constant use and not lose its resiliency.

If the material is too resilient, it is difficult to make an accurate adjustment for tracker length.

Even with these improvements a console is far from being silent. The only bellfounder making near-silent consoles is the John Taylor & Company. They use the finest quality wood and their metallic parts and accessories are beautifully chrome-plated. The workmanship on their consoles is sublime.

Instead of the axle at the back of the console on which the keys pivot, leather may also be used with good results. Leather, as often seen in the consoles of the Petit & Fritsen Bellfoundry, is completely noiseless and adds no friction.

Before ending this chapter there are two points which must be mentioned, for they receive little attention during the planning of a carillon installation: the lighting and heating of the playing cabin.

It is often satisfactory to install a double bulb fluorescent fixture on the ceiling above the bench and music rack.

A good solution to the problem of heating the playing cabin is the purchase of a portable ventilator heater which is available in various styles. It is also recommended that one or two electrical panel radiators be installed which can be regulated by a thermostat so that the cabin can be kept dry and at an ideal temperature. Proper ventilation is also necessary to prevent condensation in the cabin.

Certain tools should be kept in the playing cabin to aid in periodic repairs. The following are recommended: a bench vice, several monkey wrenches, pliers with rounded jaws and

straight jaws, double-levered wire cutters, a screwdriver, a mold to form an 'eye' connection, extra wire at various lengths, copper sheaths, a hammer, and regular iron wire.⁹ All of these facilitate the quick repair of a broken wire and other maintenance to the carillon. It is recommended that if a well-stocked first-aid kit is not placed in the cabin, at least iodine and Band-Aids be available. Guide for the repair of a wire tracker.

Depress the key to its lowest position and secure it by means of a piece of wood or something equally as solid.¹⁰ Loosen the turnbuckle by several turns and repair the wire while keeping the clapper pulled against the side of the bell. Since the key is already depressed and the clapper is against the bell, a snug repair will be relatively close to the desired tracker length. Make the fine adjustments with the turnbuckle.

¹ Author's note: Other tropical hardwoods may be Afzelea or Azobe.

Translator's note: I have been unable to

find the correct translation for these woods. The important thing is that they be strong enough to hold the bells and also that they contain the natural oils found in tropical woods for the sake of preservation.

² Translator's note: In North America there are two galvanizing processes which are most commonly used, i.e., Electroplating and Liquid Metal.

³ Author's note: The I. T. Verdin Company in Cincinnati, Ohio, is recommended, for they have been known to do excellent maintenance work.

⁴ Translator's note: The Broek system got its name from the Dutch word broek, meaning a pair of pants which the system resembles.

⁵ Translator's note: A hinge suspension unit is best although a ball bearing hinge with Teflon is ideal.

⁶ Translator's note: After many years of research work, and debate, the North American standard for carillon consoles was agreed upon in 1970. For further information see the Bulletin, Vol. XXI, No. 1, November, 1970, published by The Guild of Carillonneurs in North America.

⁷ Author's note: For further information concerning the Mechlin standard see Luidklokken en Beiaarden in Nederland by Fred. Timmermans, pages 153-155.

Translator's note: It is considered that the simultaneous playing of a white and black key with the same hand is an improper technique although it is demanded in some contemporary compositions.

⁸ Translator's note: At the University of Michigan neoprene sole, as used on shoes, was installed on the pedal surfaces, and has proven very satisfactory.

⁹ Translator's note: Any type of strong but pliable iron wire will facilitate emergency repairs, even bailing wire.

¹⁰ Translator's note: If a piece of wood is not available to hold the key down while the tracker is being repaired, a small amount of ingenuity is required: a rolled telephone directory works wonders.

CHAPTER XVI

AUTOMATIC PLAYERS¹

- A. Player drum with fixed pegs
- B. Player drum with adjustable pegs
- C. Electric chiming apparatus
- D. Pneumatic chiming apparatus

A. Player drum with fixed pegs

Early automatic player drums were constructed of wood but later were replaced by brass or iron drums which were usually 1 to 2 meters wide and 1-1/2 to 2 meters in diameter. The first brass player drum was installed in the Nieuwe Kerk in Delft and is still being used today. After the city councilmen of Delft instructed Francois Hemony to cast this drum in 1660 and after he was informed by Jan van Call, of Nijmegen, of the latest innovations for player drums, it was cast by Hemony in 1663. In the same year it was installed in the Nieuwe Kerk Tower by Jurriaan Sprakel, who was a colleague of the Hemony brothers and installed many carillons for them.

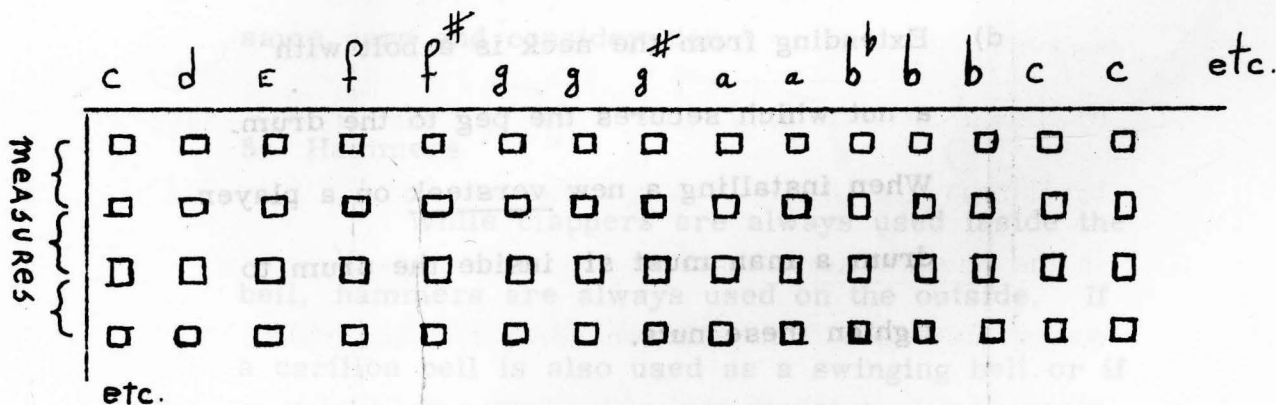
The parts of an automatic player drum

mechanism are:

- 1) Drum
- 2) Pegs
- 3) Levers
- 4) Trackers
- 5) Hammers

1) Drum

Along the surface of the player drum are many rows of square holes. Vertically these are spaced to form measures and horizontally each hole corresponds to a hammer for a bell. Occasionally bells which are most used will have two or three hammers, hence rows of holes on the player drum, so that quick repeated notes may be rendered. After a hammer strikes a bell, there is a time lag before it is once again in position for another strike.



2) Pegs

Metal pegs are placed and secured in the holes corresponding to the music being applied on the drum (the music especially written for the player drum is called verstekingen in Dutch). As the drum slowly rotates, these pegs trip the levers which pull the hammers up from their resting place just above the bell and then allows them to fall against the bell.

The parts of the peg are:

- a) the beak which trips the lever and lifts the hammer.
- b) the bridge which rests against the drum for additional support. These are only on pegs which have two beaks, thus playing two notes on the same bell.
- c) The neck is square and fits snugly into the holes on the drum.
- d) Extending from the neck is a bolt with a nut which secures the peg to the drum.

When installing a new versteek on a player drum a man must sit inside the drum to tighten these nuts.

3) Levers

The levers, sometimes called tripping bars, are aligned on an axle which is parallel to the axle of the drum. The levers are usually placed in front of the drum but sometimes are above the drum. As the drum turns, much force is put on the power source, the drum, and the pegs. The levers are constructed so that most leverage is on the side of the axle which pulls the tracker to the hammer. Therefore the pegs are only about an inch high, but they pull the hammer 3 to 4 inches up from the bell. Springs are installed under the hammers to keep them from resting against the bell.

4) Trackers

As on the carillon console, these trackers are adjustable with a turnbuckle and demand the same care and consideration.

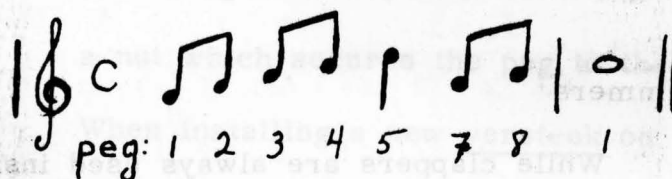
5) Hammers

While clappers are always used inside the bell, hammers are always used on the outside. If a carillon bell is also used as a swinging bell or if

a bell is unfavorably placed in the bellchamber, a hammer is connected to the carillon console instead of a clapper. When the hammer falls against the bell the spring is deflected and immediately lifts the hammer from the bell. If, when playing the carillon, a bell sounds muted, the problem may well be that a hammer is laying against the side of the bell. Often the hammer may simply need a new spring.

The Verstekingen² for a player drum with fixed pegs.

Commonly the vertical distance between the rows of holes on a player drum is one 4/4 measure which can be divided into eighth notes. For this reason pegs are available which have eight different positions for the beak. These pegs are numbered as first 8th, second 8th, third 8th, etc., as seen in the following example:



FIRST NOTE
IS "g"

In this example both an a and b appear twice in one measure and, for most player drums

with fixed pegs, this would not cause a problem.

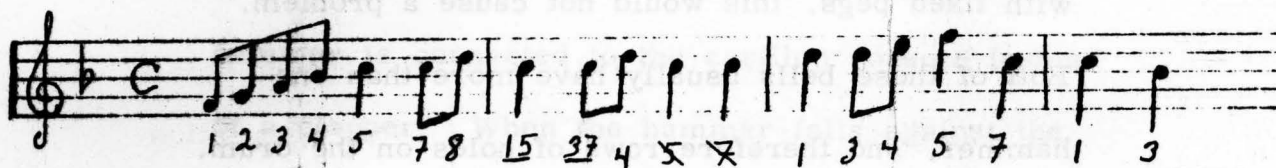
Both of these bells usually have more than one hammer, and therefore rows of holes on the drum.

However, another possible solution for repeated notes within a measure is the use of combination pegs, which instead of having only one beak, have two. Because of the necessary time lapse between the striking of a hammer and its return to the ready position, repeated notes only a distance of 1-4 may be accomplished with combination pegs.

Some carillons demand a 1-5 time lapse. Keeping the time lapse in mind it can readily be seen that combination pegs are available only in the following proportions:

1-4	2-5	3-6	4-7	5-8
1-5	2-6	3-7	4-8	
1-6	2-7	3-8		
1-7	2-8			
1-8				

The following example illustrates the solution to the problem of having only two hammers per bell, and yet the second measure demands one bell to sound four times.



Ritardandos, triplets, and notes with less time value than an eighth are impossible to install on these drums. There were times when sixteenth notes were installed on a drum with fixed pegs, but the execution was always very poor and indistinct, because the hammers seldom fell at the exact time.³

One man, and sometimes two, often sit inside the drum to tighten and secure the pegs as they are being installed. Since the pegs for the hour and half hour strike⁴ are nearly always permanently placed on the drum, it is necessary to find the exact starting place for the versteek by counting back from the hour or half hour peg the number of measures in the versteek. It is always best to number the measures of a versteek as it is being written.

Measures are usually numbered on the drum, and by

correlating these numbers, an error (which is next to impossible to correct) may be averted while installing the versteek on the drum. The installation of the versteek usually takes an afternoon and often an entire day.

An example of a good distribution of a drum with 120 measures is 72 measures for the hour, 4 measures for the first quarter, 36 measures for the half hour, and 8 measures for the third quarter.

In order to position the pegs exactly on the horizontal rows, a ruler-like guide (called versteeklat in Dutch) is laid on the surface of the drum.

A steady revolution of the drum is absolutely necessary and is possible with the installation of a drag-brake to the drum. This is particularly important when large chords are used, for the pegs encounter much resistance when tilting the levers which lift the hammers. Without a steady and even revolution the voorslag will sound arhythmic. In addition to the dragbrake the weights, which usually descend deep through the shaft of the tower and

actually power the drum, must be heavy enough for the task. Formerly these weights had to be rewound by the tower watcher once or twice a day. Today the weights are usually lifted by an electric motor. Never, even with a gear system, should an electric motor directly power the drum.

B. Player drum with adjustable pegs

The major difference between a drum with fixed pegs and a drum with adjustable pegs is that around the circumference of the drum with adjustable pegs, encircling grooves are lathed to the width of the pegs. The pegs fit snugly into these grooves, stopping all sideways movement. There are many more holes around the circumference of this drum because the first mentioned drum has but one hole for each measure while the drum with adjustable pegs has three. These holes are round, having a diameter of approximately 6 mm.

The pegs are also different, for the adjustable pegs consist of two detachable parts.

The first part is an L-shaped unit which forms the beak and a bridge. An elongated slot, sometimes open at the end, has been drilled in the bridge which allows for the peg to be adjustable. Once this unit has been placed at the correct position on the drum, in accordance with the note value which it is meant to represent, the second part, namely a nut and bolt, is inserted through the slot on the bridge and secured.

The unattached ruler-like versteeklat of the drum with fixed pegs is replaced by an attached iron bar (hoekijzer in Dutch) which has the names of the notes corresponding with the grooves on the drum and the number of hammers for each bell.

This is used as a guide for the proper positioning of the pegs, which are adjustable up or down, according to the intended note value.

When installing a versteek on a drum with adjustable pegs, care must be given that all pegs of a given note value are tightened and secured before moving on to the next note value. This is not true for drums with fixed pegs.

The advantages of a drum with adjustable pegs are many. First, any and all rhythmic figures may be used; even ritardandos may be realized. Small variations in dynamics are possible when pegs with beaks of varied lengths are used. When the beak is longer, the hammer will be lifted higher and strike the bell harder. Although sound in principle, this practice is poorly executed.

In regards to rhythm and note value, the correct placing of the pegs on the drum is accomplished by the use of a metrically divided note value guide (verdeelschijf in Dutch). This note value guide is connected to the drum by a system of gears and is turned by a crank. Each turn of the crank advances the drum a certain metric distance. Different tempos may be installed on the same drum for there are metronome calculations on the gear system between the note value guide and the drum. When this convenience is not available, often there are marks along the rim of the drum which the installer can use with the help of a metronome. Occasionally there are different note value guides

for different tempos. It is unfortunate that the system for installing a versteek on a drum with adjustable pegs has not yet been standardized.

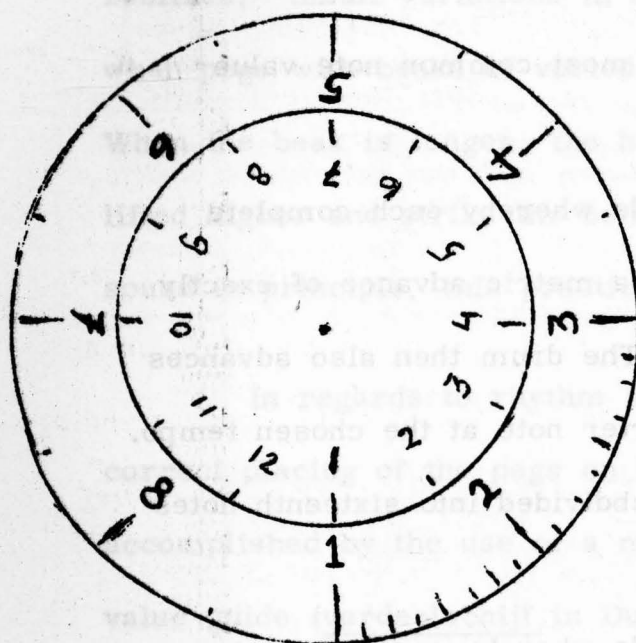
Two of the most common note value guides are:

1) the guide whereby each complete revolution produces a metric advance of exactly one quarter note. The drum then also advances a distance of a quarter note at the chosen tempo. The notes can be subdivided into sixteenth notes and triplets.

2) the guide whereby each complete revolution produces a metric advance of exactly one 4/4 measure.

This last note value guide appears to be the best. There is a minimal chance for mistake since the installer knows exactly where he is within a measure. By using the markings of the music and the drum he can find where he is within the versteek. Moreover, this system allows for beautiful ritardandos to be executed.

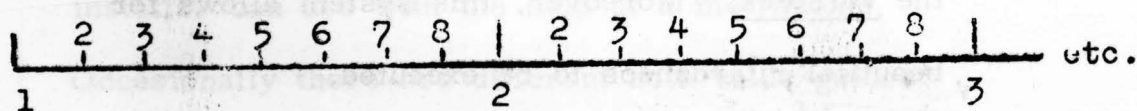
Below is a more precise explanation and example of this note value guide. One complete turn advances the drum one 4/4 measure.



The outer circle subdivides the measure into eighth notes.

The inner subdivisions are used for triplets and possibly for measures with eight beats.

In order to obtain a proper insight into the use of the subdivisions on the outer circle, a portion of that circle is illustrated on the straight line below. Below the line are the numbers as they appear on the note value guide. The numbers above the line do not appear on the note value guide but are indicated by marks.



Using the lower line as the initial guide it is found that:

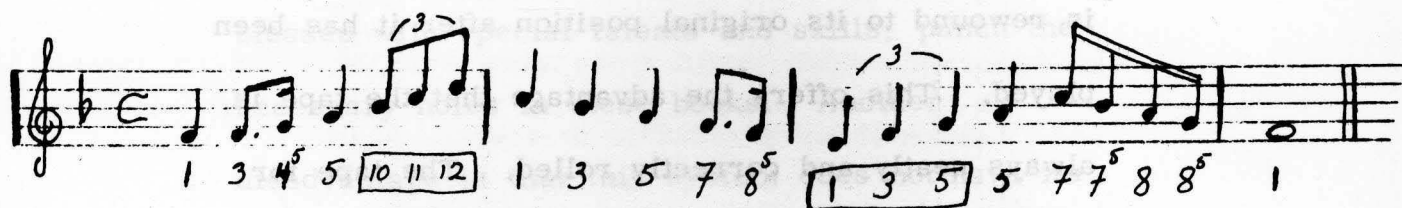
from 1 to 3 is a quarter note

from 1 to 2 is an 8th note

from 1 to 1.5 is a 16th note
(the .5 appearing above the line)

from 1 to 1.3 is a 32nd note.

Below is an example of the numbering system necessary for a versteek that is to be installed on a drum with adjustable pegs. For a better understanding and for averting errors, the numbers from the inner circle of the note value guide are always enclosed.



C. Electric chiming apparatus

This method of ringing the voorslag is a relatively recent discovery but produces the same sound from the bells as the player drums. It employs a wide plastic tape with punched holes

which close electric circuits and activate hammers electromagnetically. These electrically activated hammer units are usually placed on the outside of the bells although they may be installed on the inside. However, they are still called hammers.

Both the Eijsbouts and Petit & Fritsen

Bellfoundries have designed and developed excellent apparatuses for this purpose. The Eijsbouts Bellfoundry uses an endless plastic tape⁵ which has its ends secured with adhesive tape. The Petit & Fritsen Bellfoundry uses an apparatus which has the tape ends secured in two rollers and the tape is rewound to its original position after it has been played. This offers the advantage that the tape is always neatly and correctly rolled. The tape for the chiming apparatus used by the Eijsbouts Bellfoundry lies folded in a protective trough under the apparatus. Care must be given that the ends are securely fastened. Both systems use the principle of little metal levers falling through holes punched in the plastic tape onto a metal roller underneath the tape, thus closing the electric

circuit. In practice both systems are quite satisfactory if proper care and maintenance are given.

An additional apparatus for the punching of plastic tapes is necessary and is available, with detailed instructions, from both bellfoundries.

The Van Bergen Bellfoundry has developed an automatic chiming apparatus which uses punched cardboard books, such as those used in the street organs in the Netherlands. The major objection to this system is that the carillonneur cannot, unless blessed with special talents and skills, punch the necessary holes in these books. Another disadvantage is that this system does not have its own separate hammers for the bells, but rather is connected to the keys of the carillon console, thereby using the clappers. Consequently, the carillonneur sits behind a very obstreperous console.

Earlier the Petit & Fritsen Bellfoundry used a system called Korfhagen which also had the disadvantage that the carillonneur could not make

his own perforated tapes. The apparatus itself was of outstanding quality but the making of the perforated tapes was a costly matter.

Yet an older chiming apparatus which was used by the Eijsbouts Bellfoundry consisted of a small wooden drum (in actuality a miniature player drum) into which the carillonneur inserted little spikes so that as the drum turned, contact was made with long metal levers, the circuit closed and the bells played. This system proved of little practical use.

The Petit & Fritsen Bellfoundry once had an apparatus which would move with stepwise jerks and, instead of holes punched in a tape, braille-like tangible dots were placed on the band. This system also proved of little value and only one such system was installed.

D. Pneumatic chiming apparatus

The Heinrich Voigt Company in Frankfurt a/Main, Germany, which builds pneumatic organs,

has developed a pneumatic chiming apparatus which offers quite satisfactory results. However, like the apparatus tried by the Van Bergen Bellfoundry, this pneumatic system used cardboard books, therefore having all the entailing drawbacks.

Examples of the above described automatic playing apparatuses can be found in the following cities:

Delft -- player drum with fixed pegs.

Amersfoort -- player drum with adjustable

pegs having a note value guide that

advances one quarter note with every

complete rotation.

Leiden -- player drum with adjustable pegs

having a note value guide that advances

one 4/4 measure with every complete

rotation.

Zeist -- electric chiming apparatus with a

metallic brush which makes contact

with the roller.

Naaldwijk -- electronic chiming apparatus

with little levers.

Utrecht -- The Gerardus Majella system, using
the braille-like tangible dots designed by
the Petit & Fritsen Bellfoundry.

Venlo -- Korfhagen system.

Gorinchem -- Petit & Fritsen apparatus.

Emmeloord -- Eijsbouts apparatus.

Nijmegen -- Van Bergen apparatus.

Frankfurt -- Voigt system.

¹ Translator's note: The voorslag (before strike) or automatic player is used in the Low Countries for the same purpose as that of the Westminster Quarters used in North America and other countries, namely as a time indicator and announcer that the hour strike is about to sound. Instead of only the four bells required for the Westminster Quarters, a voorslag may encompass two or more octaves. Music which is especially written and numbered for installation on a player drum is called a versteek (singular), versteking (plural). Many times the first quarter will sound a 4 measure phrase, the half hour an old folksong, the third quarter an 8 measure phrase, and the hour a chorale. In actuality a voorslag is nothing more than a sophisticated and gigantic music box which sounds over the entire city. Since installing new music on a voorslag is a difficult and time consuming task, the music is usually changed only once or twice a year. I do not take pride in the fact that the citizens of Amersfoort, Holland, had to listen to a wrong note which I installed on their voorslag every hour for over a year's duration. It is very difficult, if not impossible, to correct an error on the voorslag. There are very few examples of player drums in North America although there has been a recent proliferation of electric chiming apparatuses.

² Author's note: Each different system for ringing the voorslag requires its particular style of writing a versteek.

³ Author's note: There is certain justification that the voorslag was often called rammel (racket) in Belgium.

⁴ Translator's note: It is common in the Low Countries to have a half hour strike and an hour strike. Usually the half hour strike is rung on a bell an interval of a 4th or 5th higher than the bell used for the hour strike. If the time is 2:30 it is said in Dutch as "half three," therefore the half hour strike will ring three times indicating that we are now in the third hour. At first it is confusing, but later convenient.

⁵ Translator's note: Better described as a 'band' but is called a tape.

CHAPTER XVII

INSTRUCTIONS FOR WRITING A VERSTEEK

- A. For a voorslag with a 2 octave range of light bells
- B. For a voorslag with a 3 octave range of heavy bells
- A. The versteek, written for a light carillon on which the voorslag has a range of 2 octaves, may be scored on either one or two staves. It is always best to keep the music in the keys closely related to C, i.e., the keys of G and F with their respective relative minors. The melody is often doubled at the octave. The following is an example of a simple two voice arrangement.

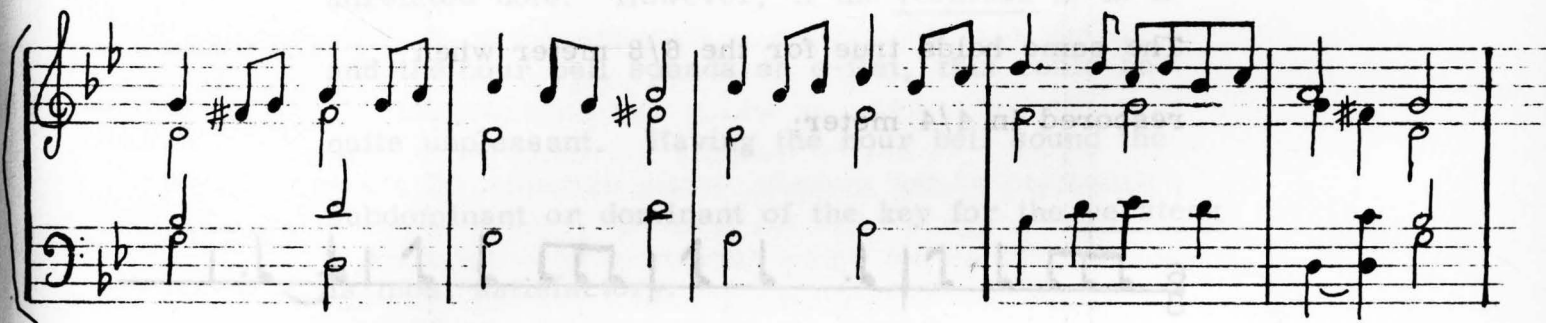


Below is a nicer three voice arrangement.



B. For a voorslag of heavy bells with a 3 octave range, the versteek is commonly written in the keys G, C, or F, or their relative minors.

In writing a versteek it is wise to keep the following hints in mind. Keep the bass line thin so that it does not overpower the melody if it is in the soprano. Set the meter at the beginning of the piece by using full chords on the accented beats of the first measure, i.e., the 1st and 3rd beats of a 4/4 measure and the 1st and perhaps 3rd beat of a 3/4 measure. Here is an example:



The first staff of music is in 3/4 time. It begins with a treble clef and a key signature of one flat (B-flat). The melody consists of the following notes: G4 (quarter), A4 (quarter), Bb4 (quarter), A4 (quarter), G4 (quarter), F4 (quarter), E4 (quarter), D4 (half).

[illegible]

Handwritten musical notation for two staves. The top staff is in 6/8 time and the bottom staff is in 4/4 time. Both staves contain a sequence of notes and rests, with the bottom staff including fingerings (1-8) and a breath mark.

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The correct choice of a key signature for the versteek is very important when the voorslag is limited to 2 octaves or when the carillon is tuned in the mean-tone temperament.¹

Distribution of the notes across the entire width of a 3 octave drum offers the best results.

It is often possible to select a bell for the hour strike having a pitch related to the key chosen for the versteek. When this is not possible it is not disturbing to have the hour strike sound an unrelated note. However, if the versteek is in D and the hour bell sounds an e-flat, this could be quite unpleasant. Having the hour bell sound the subdominant or dominant of the key for the versteek is most satisfactory.

It must be mentioned that popular songs or melodies should not be installed on the voorslag, especially if the player drum is changed only once or twice a year, for the public will soon become weary of its repetition. Therefore, a good solution would be to install a chorale, gavotte, march, or

menuet, etc. for the hour and a rather unfamiliar folksong for the half hour.

It is possible that the final cadence might have five or more voices; however, never use a note lower than the lowest note of the final chord in the concluding measures. The only exception to this rule is the dominant, which gives a feeling of termination. Never use a sixth chord as the final chord, for the resulting minor second is disturbing during the decay.

Below are further examples of how a versteek may be written. Example (a) is a beginning of a folksong which has an excellent delineation of the melody, while example (b) shows how a part of the same song may be written as a canon. This music was written for a voorslag having a range of 2 octaves plus the upper c-sharp and d.



Never put the melody in a middle voice since it is much too difficult to follow. Since the versteek must be written with the range of the voorslag and the hammer availability per bell in mind, it is not always possible to have three repeated eighth notes if the bell has only three hammers.

Since the electric chiming apparatuses which use punched plastic tapes have only one

hammer per bell, the quickest repetition possible is an eighth note at M.M. 120 or a sixteenth note at M.M. 60.

The music installed on the voorslag must be somewhat slower in tempo than if played on the carillon or it will lose its perceptivity and clearness.

The electromagnetic hammer units, as applied to the electric chiming apparatuses manufactured by the Eijsbouts and Petit & Fritsen Bellfoundries, can be adjusted to strike the bells loud or soft. This is not dynamic control, but rather an overall and rather unchangeable volume control.

¹ Translator's note: See Chapter XXV.

CHAPTER XVIII

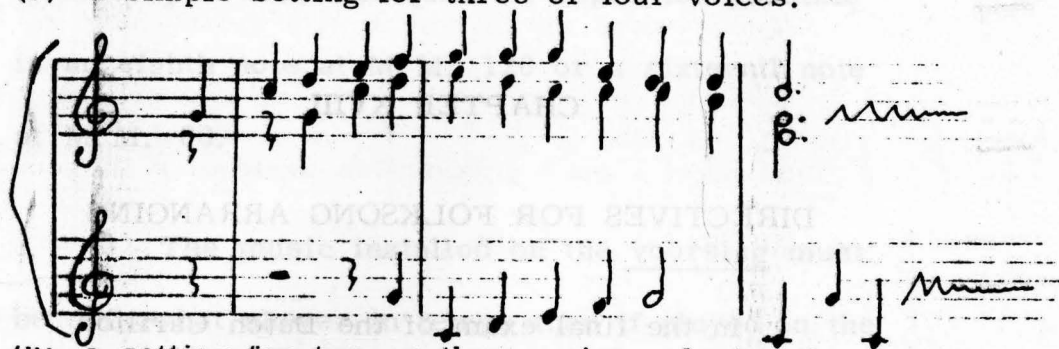
DIRECTIVES FOR FOLKSONG ARRANGING

In the final exam of the Dutch Carillon School, the student is required to arrange a folksong for a light carillon of 2-1/2 octaves and also one for a heavy carillon of 4 octaves.

Music for a carillon of 2-1/2 octaves (usually c^1 to g^3) is written on two treble-clef scores. For the exam at the Carillon School, the student is given a melody for which he is expected to make an arrangement at sight.¹ It is expected that his arrangement will be interesting and show ingenuity. The student must also make an idiomatic arrangement for a 4 octave carillon and not just a simple harmonization.

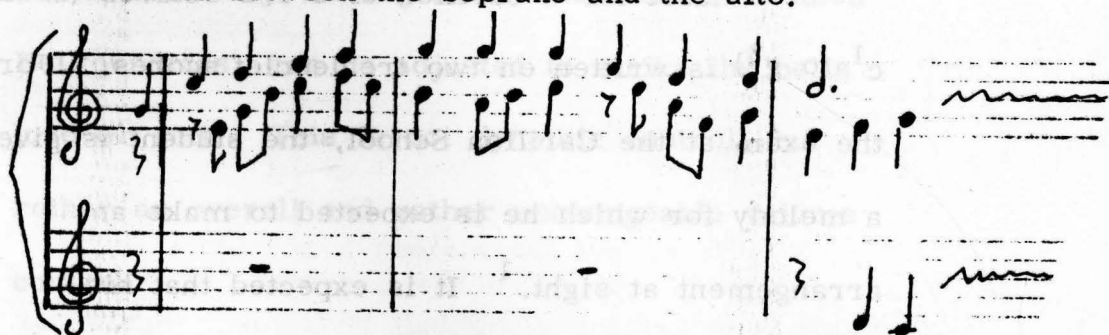
Some possibilities are:

- (1) a simple setting for three or four voices.

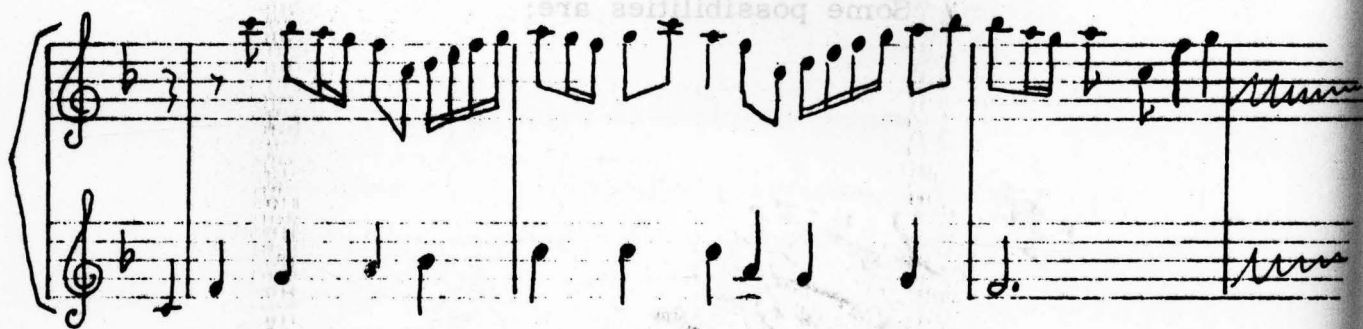


- (2) a setting for two or three voices placing the melody in the soprano and having a moving alto line and, if desired, a quiet bass line.

There should never be more than an octave interval between the soprano and the alto.



- (3) a simple two voice arrangement with the melody in the bass line which is to be played either with the left hand or the feet, accompanied by a flowing soprano line. Intervals of more than an octave are now acceptable.



(4) a three voice arrangement with the melody in the alto line, keeping the moving soprano line and quiet bass. Again it is preferable to keep the distance between the soprano and the alto within an octave, although this is not a set rule.

Remember that the soprano line must be played with one hand and therefore the arrangement must be taken at a practical tempo. The bass line, as in the following example, should be less active.



It is possible to include many different techniques for variety and interest, such as ornamentation, broken chords, arpeggios, etc.

The music written for a standard carillon (4 octaves) is scored with a treble and bass clef. More variations of arranging techniques are now possible and should be incorporated into the music.

The arranger can use the large bells, the greater range, and effects idiomatic to large bells and carillons.

Doubling the melody at the octave gives an outstanding effect and suitable emphasis to a melodic line. When doubling the melody the bass line may be a quiet independent voice in the pedal, which should be taken at a rather slow tempo, especially on large bells, or a full harmonization with two or three voices in the pedal.

For a greater insight into the art of arranging songs for the carillon, study the following music which is published by the Dutch Carillon School.

Merck toch hoe sterk

The first arrangement is a normal harmonization for three and four voices. The second has broken chords and a quiet bass while the third has the melody with octave doubling and chords of two or more voices in the pedal.

De nachtegaal die zank een lied

A three voice arrangement with a modified 'basso ostinato'.

Het waren twee Koningskinderen

An arrangement with a light polyphonic texture.

Wek op, wek op dat herte mijn

The first arrangement uses melodic octave doubling above a pedal point.

Gekwetst ben ik van binnen

This arrangement is treated with a somber harmonization.

Variations on "De winter is vergangen"

The first arrangement uses melodic octave doubling. The second is a two voice arrangement with the melody in the soprano. The third places the melody in the pedal in a minor key. The fourth incorporates the melody into triplets. The fifth uses a slower melody in the pedal with faster passages of sixteenth notes in the manual as accompaniment.

The sixth and final arrangement places the melody in chords in the manual above a descending 'basso ostinato' in the pedal.

Variations on "Allein Gott in der Hoh' sei Ehr"

The first variation is a simple four voice harmonization. The second places the melody in the soprano with a complimentary part also on the manual. The third arrangement incorporates the melody in the soprano line above a pedal point. The fourth and final variation places the melody in the pedal below an accompaniment of parallel quarter notes in the manual.

Further study of the arrangements published by the Dutch Carillon School, such as the Christmas songs, Negro Spirituals, and the folksongs from different countries, would be most beneficial for the student desiring a better understanding of the art of arranging for the carillon. More beneficial still would be the actual writing of arrangements by the student, incorporating the above mentioned techniques.

À vue arranging is considered important for the complete carillonneur. Arranging at sight is not easy, but diligent practice of the following techniques will help the student learn and master this important part of carillon performance.

1. Play the chosen melody, which could be a folksong or hymn (leaving popular songs until this art is mastered), with two voices on the manual, keeping it very simple at first. Later incorporate triplets and sixteenth notes into the playing. It is possible to use a free atonal accompaniment and also a free rhythm.

2. Add a quiet and thin bass line. At first this could possibly be a pedal point. Later the pedal harmonization could fall on the accented beats of the measures. A canon treatment, especially in the final measures, is very effective.

3. Practice incorporating the melody into one continuous line, accenting the melody notes. A song having a repetitious melody is ideal for practice. The performer must concentrate on what he is doing or the melody will be lost. Keeping

your eyes fixed on the melody line will be a great benefit in keeping the rhythm steady and flowing.

4. Practice broken chords in which the melody remains clearly perceptible.

Trite as it may sound, this description of techniques used in arranging can not be ended without saying that practice makes perfect. Be sure to remain with one stylistic technique throughout an entire variation. It is very disconcerting if the performer changes his arranging style in the middle of a melody.

¹ Translator's note: Commonly called à vue arranging. The carillonneur has a melody in front of him on which he makes an arrangement at sight in no predetermined manner or style. Like an improvisation this music is for the present, never to be copied or heard again. The most important criteria for a good à vue arrangement or improvisation is that it must be musical. Another criteria is that it be interesting. No matter how many times the performer improvises on a certain melody, it will never sound the same. À vue arranging and improvisation are arts in their own right and extend the performing techniques of the carillonneur to their limits.

CHAPTER XIX

FUNDAMENTAL DEFINITIONS AND DESCRIPTIONS OF A BELL

A bell is a round, somewhat dish-like body and cast of bronze to an exacting profile. Every horizontal plane of a bell is circular and every vertical plane is symmetrical to its axis.

Bell bronze is an alloy composed chiefly of two metals, copper and tin, having a ratio of 18% to 20% tin to approximately 78% copper. As a rule, large bells have a higher percentage of copper and small bells a higher percentage of tin. Certain contaminants can be anticipated and tolerated, such as 1% lead, 2% zinc, and small amounts of antimony, iron, nickel, and others. The melting point of bronze is about 900° C. and the temperature at which the bell is cast is approximately 1100° C. The specific gravity of bronze is 8.8.

Molds are used to shape the external and internal form of the bell. This form is called the

profile which, by definition, is the varied proportion of the vertical plane in relation to the axis of the bell. The size dimension and pitch of a bell is determined by the diameter of the mouth.

The composite sound of the bell is a complex series of harmonics,¹ the lowest of which is known as the 'hum-tone'.

A well tuned bell has overtones which form related intervals to each other and are as harmonic as possible. The harmonic structure of a bell is directly dependent on the profile, which must be accurately designed and, after the bell has been cast, must be corrected to perfection (tuned).

The correct interior tuning² for a bell places the harmonics in the following order: for a c^1 bell, $c - c^1 - e\text{-flat}^1 - g^1 - c^2$ and called hum-tone fundamental (prime), minor third, fifth (quint), and nominal (octave), respectively.

Since the composite sound of the bell is a function of the profile, not all bells can be

correctly tuned interiorly. This is especially true for early bells, bells of the Middle Ages, and bells cast during the period of decline for the art of bellfounding.

Tuning a half tone is so difficult that interior tuning is most often acceptable when accurate to $1/16$ th of a half tone (when using adjustable tuning forks), or to a few 'cents' (when using an electronic measuring apparatus). The tuning techniques using adjustable tuning forks are now obsolete, although these tuning forks are often used to measure existing bells in towers. One 'cent' is $1/1200$ of an octave, thus $1/100$ th of a half tone. The 'cent' deviations are given below with regard to the normal naming of tones: c -- plus 10, c^1 -- minus 35, e-flat¹ -- plus 26, g^1 -- minus 67, c^2 -- plus 6 cents. As can be seen, the fundamental of this bell is disturbingly low when compared with the strike-note, which should have the same frequency. (See Chapter XXI.)

The composite sound of a bell is generated by the vibrations of the bell wall.

The pitch and intensity of each harmonic is the result of a certain number of vibrations (cycles) per unit of time. Different harmonics are emitted from different sections of the bell wall. For example, when the pitch of a hum-tone, which is generated low on the sound-bow, is a^1 (the a above middle c), the lower section of the sound-bow is vibrating 440 cycles per second, hence 440 Hz.

In addition to the many harmonics, one, and sometimes two strike-notes may be heard. The actual pitch heard as the tone of the bell cannot be demonstrated with physics and also cannot be measured.³

Exterior tuning is the adjusting of the pitch (strike-note) to be in intervallic progression with the other bells of the carillon. As a result each bell is named after its strike-note. For example, a c^1 bell (middle c) has a hum-tone of c , a fundamental (and strike-note) of c^1 and a nominal of c^2 , but nevertheless, it is referred to as the c^1 bell.

While the interior tuning depends upon the

profile, the exterior tuning depends upon the size, weight and other dimensions of the bell. The strike-note, diameter and weight are closely related. If any two of these variables are specified, the third may be calculated. Naturally there are many different possibilities. In practice there are fixed proportions for these variables which are most acceptable. Listed below are five bells as an example. Each has different proportions, but since the ratio between these proportions is the same for each bell, they can be considered as one bell.

<u>Strike-note</u>	<u>Diameter in cm.</u>	<u>Weight in kg.</u>
c ¹	155	2,400
e ¹	123	1,380
g ¹	103	690
c ²	77	290
e ²	62	145

It is interesting to note that:

when a bell is made larger, its pitch will be lower.

when a bell is made smaller, its pitch will be higher.

when a bell is made thinner, its pitch will be lower.

when a bell is made thicker, its pitch will be higher.

After a bell has been struck, each harmonic will sound for a certain duration, generally decreasing as a function of time. The action is called interior acoustical damping or decay, while the duration is called resonance. As a rule, the higher the harmonic, the shorter the duration of decay. When the resonance of a bell is described, it usually refers to the decay duration of the hum-tone. The resonance has a decay rate of .6 to .8 times the diameter per second.

When the intensity of a harmonic is mentioned, the hum-tone is usually cited as the example. The intensity of a harmonic is many times erroneously referred to as duration of decay or resonance.

The timbre or tone color of the complex

bell sound is a result of the intensity and decay duration for each individual harmonic and their intervallic relationships.

Occasionally a fluctuation is noticed in the sound. This is caused by the increasing and decreasing intensity and frequency of one or more harmonics.

Each section of a bell has been named. It is not possible to distinguish where one part begins and another ends, for a bell is one unit. The following list is just an approximation:

lip -- the extreme lower rim of the bell.

sound-bow -- the lower and thickest part of the bell, struck by the clapper and/or hammer.

girth -- the transitional part between the sound-bow and the waist.

waist -- the cylindric vertical part of the bell.

shoulder -- the transitional section between the waist and the more horizontal head.

head -- top of bell proper.

crown -- (when applied) used for suspending
the bell.

tongue -- the clapper.

mouth -- the opening at the bottom of the bell.

Generally speaking, there are only two ways
of striking a bell, although there are several
variations to each method:

- (1) with a sphere-shaped body (clapper)
on the inner side of the bell.
- (2) with a hammer-shaped body (hammer)
on the outer side of the bell.

A swinging bell is struck by the clapper as
the bell pendulates. A tolling bell is stationary and
is struck by a hammer. This is done to note the
passing of an important person, or to announce the
hours of the day.

A carillon bell is also stationary and may
either be played by using the clappers attached by
wire trackers to the carillon console or rung by
hammers connected to the automatic chiming mechanism.

One bell may be functional for all of the above named methods of ringing; however, carillon bells are most often rung only by the clappers which are attached to the console.

A carillon is a combination of at least 23 highly tuned bells comprising a chromatic scale. The range of a carillon is fairly arbitrary, although it is recommended that it have at least three octaves plus the high c-sharp and d. If necessary, omit the low c-sharp. The standard range for a carillon today is 4 octaves. Depending on the monies available and the size of the bellchamber, the low b-flat may be added, or the low c-sharp (and possibly the e-flat) omitted.

¹ Translator's note: The word 'harmonics' is often used interchangeably with overtones or partials. The fundamental (prime) is not an overtone, hence, the first overtone is the minor third. The word 'harmonics' indicates all sounds including the fundamental.

It is interesting to note that while all other sound-producers have harmonic overtones, the untuned bell is nonharmonic. This is primarily due to the fact that the bell has a minor third overtone which must be highly tuned in order to be harmonic with itself.

See Chapter XX for further information.

² Translator's note: Two tuning functions are done simultaneously when tuning a bell: the first is 'interior tuning' which causes the bell to sound in tune with itself, and the second is 'exterior tuning' which places the pitch of the bell in a harmonic relationship with the other bells of the carillon.

³ Translator's note: The pitch or strike-note of a bell is a phenomenon that can not be described or reproduced. There are several different theories concerning the nature of the strike-note. See Chapter XXI.

CHAPTER XX

THE HARMONIC STRUCTURE OF A BELL

All musical tones are composite sounds containing the main sound, or fundamental, plus any number of pure tones called harmonics or overtones.¹ No musical instrument, with the exception of the synthesizer and the like, produces one pure sound, hence one vibration or frequency.

Most overtone frequencies are exact multiples of the frequency of the fundamental, but not those of the bell. After a bell is cast, it has a very rough and nonharmonic overtone series. For the bell to be used in a carillon, it first must be accurately tuned to be harmonious with itself, and then tuned to the other bells of the instrument.

This eliminates the nonharmonic qualities of the bell. This sounds simple, but unlike any other producer of musical sound, the bell has a prominent minor third overtone which cannot be eliminated: it is idiomatic to the bell.

The function of the intensity and relation of each overtone to the others in the sound produces the pitch and timbre of that sound.

The harmonics of a bell can be categorized into two groups:

A. The harmonics that occur by the vibrations of the bronze, and

B. The secondary tones which develop through the combinations of overtones and subsequent apparitions such as the individual characteristics of an ear.

Four factors are important when considering overtones:

- (1) the intervallic relationships formed
- (2) the intensity of each tone
- (3) the individual interior acoustical damping or duration of decay
- (4) the means by which the sound is started, i.e., struck with a clapper, felt piano hammer, etc.

The normal intervallic relationships between the harmonious² overtones of other musical instruments is outlined below.

Given c^1 (middle c):

$c^1 - c^2 - g^2 - c^3 - e^3 - g^3 - b\text{-flat}^3 - c^4 - d^4 -$

1 2 3 4 5 6 7 8 9

$e^4 - f\text{-sharp}^4 - g^4 - a^4 - b\text{-flat}^4 - b^4 - c^5 - \text{etc.}$

10 11 12 13 14 15 16

The numbers given below the overtones help clarify intervallic relationships and ratios of vibrations or frequencies: e. g., the relationship of the octave, fifth, and third to the fundamental is 2:1, 3:2, and 5:4, respectively. Our ears sense these overtones as sounding c^1 , thus the fundamental or pitch. The timbre of the sound is heavily dependent on the interaction of the intensity and decay duration of the harmonics. For example, a forceful or light stroke on both the piano and carillon keyboards influences the timbre of the tone. On the carillon a forceful strike will cause the clapper to contact the bell with a staccato-like motion and will bring out more of the harmonic

structure of the bell and give each overtone more intensity. The tone of the bell is more acute than if struck with a lighter touch.³ A soft strike of the clapper brings out only a few of the lower harmonics, causing the bell to sound dull, for it is the higher overtones which add brilliance and luster. Some bells have odd gaps in their harmonic series, or a shrill sound caused by too many nonharmonics. Some of the new bells cast by the European bellfoundries have higher harmonics that are clear and sharp.

Obviously not all of the harmonics of a bell can be tuned -- usually only five, although some bellfoundries tune six. Even in the aforementioned example of the harmonic structure of harmonious sound producers, some of the overtones are impure and false, such as both b-flats and f-sharp. Fortunately, these appear in the upper range of the series.

There are instruments which have no structured harmonic series, such as percussive instruments like drums, timpani, gongs, and

triangles. The ratio of nonharmonic overtones for the drum is so great that no definable pitch is produced, but rather only a sound composed of many nonharmonic overtones.

The bell has its own harmonic structure. After casting, the overtone series of a bell is nonharmonic, but by the proper selection of a profile and the tuning of a number of overtones, a harmonic structure and sound is built. The harmonic structure of a well-tuned bell is as follows:

Given c^1 (middle c)

hum-tone	-	fundamental	-	minor third	-	fifth
		(prime)				(quint)
c		c^1		$e\text{-flat}^1$		g^1

nominal	-	major decime	-	1st nondecime
(octave)				
c^2		e^2		f^2

2nd nondecime	-	duodecime	-	major tridecime
$f\text{-sharp}^2$		g^2		a^2

major quarter decime	-	double octave, etc.
b^2		c^3

Of these, only the first five are usually tuned. The duration of decay for these five most

important harmonics and their intensity ratios
are shown below schematically:

c (F)	-----
c ¹ (MF)	-----
e-flat ¹ (FF)	-----
g ¹ (P)	-----
c ² (FFF)	-----

After a bell is struck, the harmonics are emitted from the sides of the vibrating bell. Due to the fact that each harmonic has its own frequency, the sides of the bell will simultaneously vibrate differently at various places. The shape of the vibrations for each overtone will greatly differ. These vibrations travel horizontally and vertically throughout the bell.

If one were to walk around a bell shortly after it had been struck, he would experience the phenomenon that the intensity of the hum-tone would be stronger at the four compass points, in relation to the strike point. The places on a bell which emit the greatest intensity of the hum-tone are:

1. the strike point
2. 90° to the left of the strike point
3. 90° to the right of the strike point
4. directly opposite the strike point

This phenomenon occurs because the characteristic shape for the hum-tone vibration travels horizontally around the bell. Because of this there are four places around the bell which are not emitting the hum-tone (called 'nodes', being the pivotal points for the vibrations) and four places around the bell which vibrate at the maximum (called 'antinodes'⁴).

Using the c^1 bell as an example, we know that the fundamental (c^1), and the first nondecime (f^2) have the same vibration shape. Some overtones, however, have six nodes and six antinodes such as the minor third ($e\text{-flat}^1$), the fifth (g^1), and the second nondecime (f^2). Still other overtones have eight nodes and eight antinodes such as the nominal (c^2), the major decime (e^2), and the major tridecime (a^2).

Due to the fact that the wall of the bell is vibrating, these nodes and antinodes may be found having a related horizontal position on any given section of the bell. The vertical connection between the nodes is called 'nodal-lines'. Thus the hum-tone has, in addition to its horizontal vibration shape, four vertical nodal-lines, the minor third has six, etc. Speaking about the vibration theory in general terms, the nodal-lines are symbolized by an 's' and are applicable by dividing the number of nodes in half. Thus the hum-tone is described as $s = 2$, the minor third $s = 3$, and the nominal $s = 4$, etc.

The vibrations for the hum-tone are the simplest in the entire bell. After the bell has been struck, the entire bell, except for the head, vibrates in many different directions. These minute pulsations of the profile produce the complex bell sound.

The fundamental has its nodes on the girth just above the sound-bow and therefore, like the hum-tone, there are four places around the girth which do not sound the fundamental. Because of the

close proximity of the hum-tone and the fundamental, opposite horizontal vibrations occur. The horizontal section of a bell on which the nodes for any given overtone are located is called the 'nodal-circle', and the vibrations emitted from adjoining nodal-circles overlap.

The minor third, nominal, duodecime, and the double octave have nodal-circles on the waist, while the fifth, major decime, and the major quarter decime have nodal-circles on the sound-bow.

Some overtones are produced using two nodal-circles, such as the two nondecimes. One is located on the sound-bow and the other on the waist. Still others have three nodal-circles, but since they are produced near the same position on the bell wall as other more prominent overtones, they can not be tuned and are of little importance to the bell except for adding color to the total sound. These are high in the harmonic structure and are scarcely perceptible.

In order to further distinguish the vibrations

of the overtones, these may be classified in the following manner:

Group I -- overtones having their nodal-circles on the waist

Group II -- overtones having their nodal-circles on the sound-bow

Group III -- overtones having their nodal-circles on both the waist and the sound-bow

Group IV -- overtones having three nodal-circles

The hum-tone can then be described as being the lowest tone of the first group and the fundamental as the lowest tone of the second group. However, the fundamental actually has its nodal-circle in the girth, being just above the sound-bow -- unlike the other overtones in Group II.

The following two diagrams illustrate these relationships quite simply. The last column of the second diagram gives the 's'

number along with the group in which lies the overtone.

Diagram I:

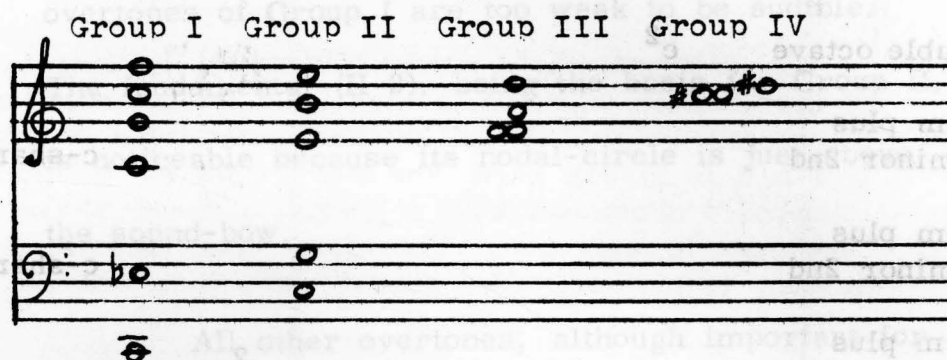


Diagram II:

(Based on the c bell)

Name:	Group I (waist)	Group II (sound-bow)	Group III (sound-bow and waist)	Group IV (3 nodal circles)	Scientific Notation
Hum-tone	C				I-2
Fundamental (prime)		c			II-2
Minor third	e-flat				I-3
Fifth (quint)		g			II-3
Nominal (octave)	c ¹				I-4
Major decime		e ¹			II-4
1st nondecime			f ¹		III-2
2nd nondecime			f ¹		III-3

Duodecime	g^1		I-5
Major tridecime		a^1	III-4
Major quarter decime		b^1	II-5
Double octave	c^2		I-6
idem plus minor 2nd		$c\text{-sharp}^2$	IV-2
idem plus minor 2nd		$c\text{-sharp}^2$	IV-3
idem plus major 2nd		d^2	III-5
idem plus augmented 2nd		$d\text{-sharp}^2$	IV-4
idem plus major 3rd	e^2		II-6
Double nondecime	f^2		I-7

There is a difference of more than 30 cents
between both the f^1 's and the $c\text{-sharp}^2$'s.

Since a tone is emitted only from the
antinodes and never from the nodes, the overtones
which do not have nodal-circles on the sound-bow or
girth are either not heard or are scarcely perceptible
at the time of the strike.

The overtones in Group I are clearly perceptible, such as the hum-tone (I-2), the minor third (I-3) and the nominal (I-4). The other overtones of Group I are too weak to be audible.

The fundamental (II-2), being the basis for Group II, is noticeable because its nodal-circle is just above the sound-bow.

All other overtones, although important for the timbre of the bell sound, are unimportant to the accurate tuning of the bell.

An overtone exhibits less intensity and resonance as it progresses upward in a group.

Included in the group of musical instruments which have nonharmonic overtone structures are the metal xylophone bars used in practice consoles for carillons. Particularly the low notes of a practice console have a noticeable nondecime which, at times, can be disturbing. This is eliminated by placing a resonator above the metal bar which makes the hum-tone more prominent over the other harmonics. It is the resonator which gives the celesta its delightful tone.

¹ Translator's note: See footnote 1 in Chapter XIX.

² Author's note: Hence the word 'harmonics'.

³ Translator's note: The dynamic control of the carillon when performed by a trained carillonneur is directly related to the harmonic structure of the bells. If a bell is struck hard, the sound consists of more intensified overtones with a greater number of the higher overtones brought out. Therefore, tone coloring and shading is primarily the product of a judicious use of dynamics, hence harmonics.

⁴ Translator's note: Often described as 'loops'. A good example of the function of the antinodes is a rubber band held taut between your hands and plucked. This pulsating back and forth is the same that occurs in the bell profile, although in miniscule proportions, and often both horizontally and vertically. The two ends of the rubber band held in the hands are the nodal points where no vibration occurs.

CHAPTER XXI

THE STRIKE-NOTE OF A BELL

The sound which the human ear interprets as the pitch of a bell is more accurately named the strike-note. Being a resultant of the nominal, the strike-note can not be demonstrated nor reproduced with measuring apparatuses such as the tuning fork or the vibrating needle.

The timbre of the strike-note is metallic and harsh but gives a clearly perceptible pitch.

At the moment the bell is struck, and for a few seconds thereafter, it dominates the composite sound of the bell with its intensity.

The pitch of the strike-note is the function of an exact one or two octave relationship between it and the strongest harmonic of the bell. Therefore, it is possible for a bell to have more than one strike-note.

The 'primary strike-note' is the most important and has a one octave relationship to the nominal (I-4). For example, if the nominal of a bell is c^2 , the strike-note will sound c^1 . Being a function of the nominal (I-4) the strike-note will be tuned as the nominal is tuned. The pitch of some bells will rise noticeably shortly after the strike. This is caused by the inaccurate tuning of the nominal. As the intensity of the strike-note fades, it is quickly overtaken by the fundamental and hum-tone.

The 'secondary strike-note', which is often noticed in large bells heavier than 700 kg., has had many names such as fourth interval strike-note, tritone strike-note, third interval strike-note, and metallic quarter.¹ Actually, it is nothing more than an overtone having a very metallic sound. Research has proven that the secondary strike-note is a function of the double nondecime (I-7) and that it sounds two octaves below its source, which places it an interval of a fourth above the fundamental. For example, if the double nondecime (I-7) sounds f^3 , the secondary strike-note will be f^1 .

Such names as third interval strike-note and tritone strike-note arise from the often inaccurately tuned nominal (I-7). Fortunately, the secondary strike-note is not often perceptible in larger bells, and appears to be directly related to the profile.

Since the primary strike-note, commonly shortened to strike-note, is the first definite pitch noticeable after a bell is struck, there is a tendency to name it after the hum-tone. For example, a bell weighing approximately 2300 kg. will produce a hum-tone having a pitch of c, so the strike-note will be called c^1 , regardless of the pitch which the fundamental sounds. The primary strike-note has also been called the 'melody tone', but this creates erroneous connotations.

The secondary strike-note is perceptible only in large bells because its source, the double nondecime, is proportionately lower on large bells. For bells lighter than approximately 700 kg., the frequency of the double nondecime is too high to cause a secondary strike-note.

The blind carillonneur of Utrecht, Jhr.

Jacob Van Eijck, observed in the 17th century that the nominal (I-4) was the strongest harmonic of a bell and, therefore, named it the slach. Francois Hemony, who was particularly careful with the tuning of the nominals in his bells, primarily retuned only the nominals of the four Van Wou swinging bells before he included them in his new carillon for the city of Kampen.

Marin Mersenne collaborated with Jacob Van Eijck to discover the ideal proportion and design of a bell.

¹ Translator's note: These names have been freely translated from the Dutch.

CHAPTER XXII

THE TUNING OF A BELL

A bell is always cast somewhat heavier than its intended weight, for during the tuning process some material is removed from the inner side of the bell. The tuning process is better described as the fine correction of the profile and is actually the function of two well-contained, simultaneous procedures. The first, interior tuning, is the alignment of the harmonic structure by the tuning of the five most important overtones so that the bell is in tune with itself. This process eliminates the nonharmonic qualities of a bell. The second, exterior tuning, aligns the strike-note to its correct pitch relationship with the other bells of the carillon.

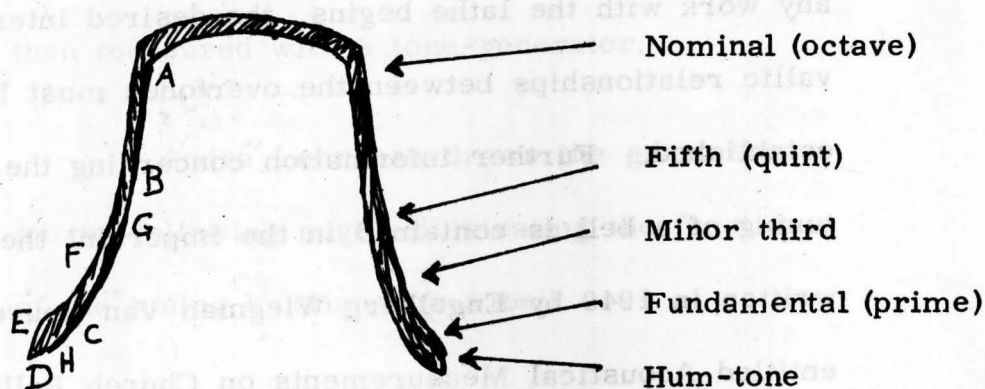
Earlier methods of tuning involved the chiseling of grooves (which were sometimes quite deep) vertically on the interior of the bell. The present method places the bell upside-down on a

lathe and grinds out the proper amount of material. Both interior and exterior tuning are performed exclusively on the inner side of the bell. The procedures could be just as successfully performed on the outside, but this would detract from the appearance of the bell and also prohibit using inscriptions and adornments.

It is interesting to note that if material were removed equally over the entire surface of the bell, not only would the composite sound of the bell change, but each harmonic would change to a different degree. When the entire surface of a bell is lathed, the fundamental will lower just a little, while the hum-tone lowers more and the higher overtones lower still more. Therefore, a virgin bell¹ must be handled with precision and care in order for it to become a well tuned bell.

The Reverend Simpson, with the cooperation of E. Dennison Taylor, master bellfounder of John Taylor & Co., Loughborough, England, rediscovered the proper procedures for tuning a bell.² In 1895

he formulated a number of rules for the tuning process, some of which are given below.



1. The nominal can be raised by lathing from H to D (or E).
2. The nominal can be lowered by lathing from H to C or from G to B, but only a semitone (100 cents).
3. The fundamental can be raised by lathing from C to D.
4. The fundamental can be lowered by lathing from C to G, and sometimes to B.
5. The minor third can be lowered by lathing from G to B.
6. The fifth can be lowered by lathing from B to G.

Since the lathing at a specific place on the bell also affects the other overtones, the process of correctly tuning a bell is very difficult, and before any work with the lathe begins, the desired intervallic relationships between the overtones must be established. Further information concerning the tuning of a bell is contained in the important thesis written in 1949 by Engelberg Wiegman Van Heuven entitled Acoustical Measurements on Church Bells and Carillons. He is in agreement with Zur Akustik der Glocken (The Acoustics of Bells) written in 1848 by Pfnor, and the articles published in the Pall Mall Magazine by the Reverend A.C. Simpson entitled "On bell tones" (1895), and "Why bells sound out of tune. How to cure them" (1896).

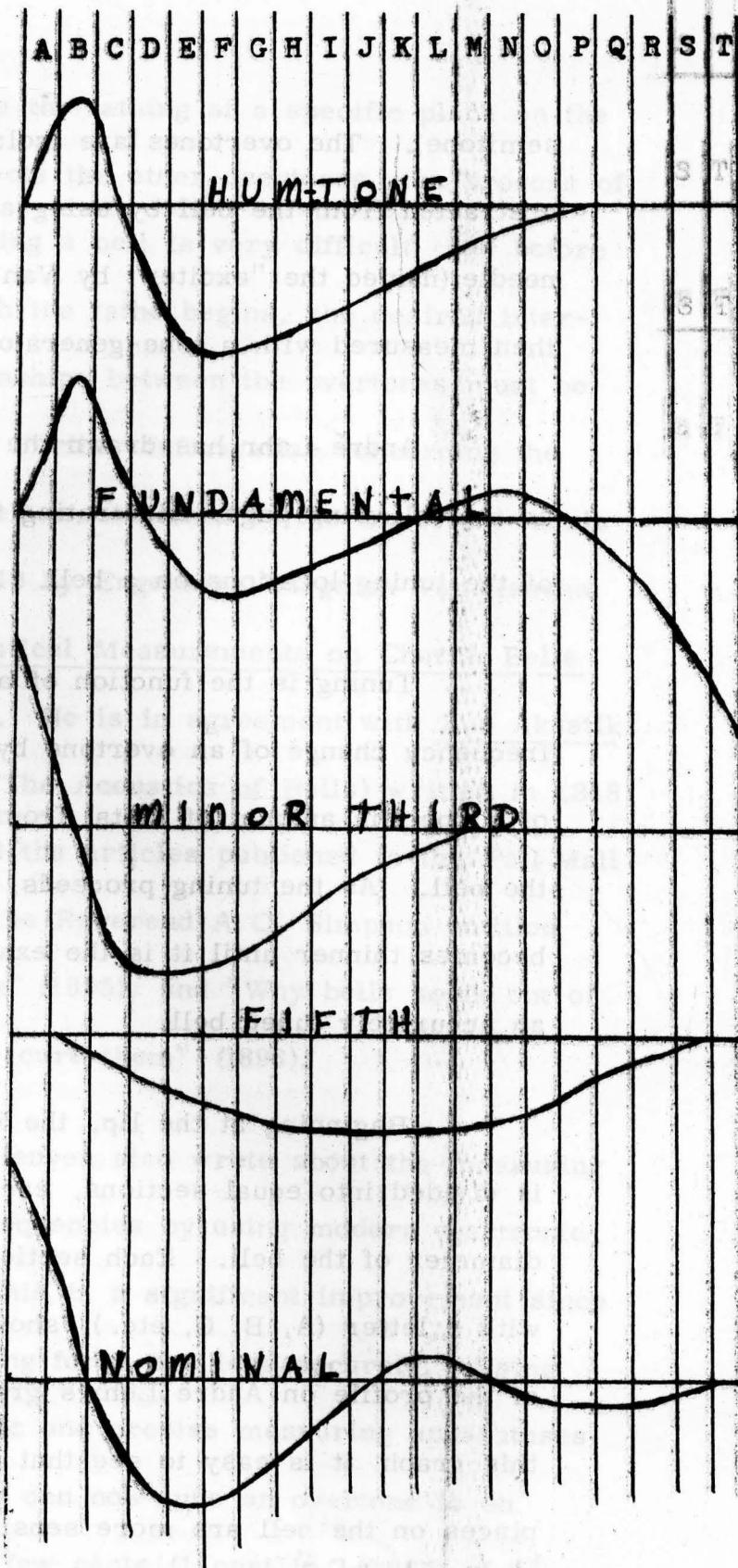
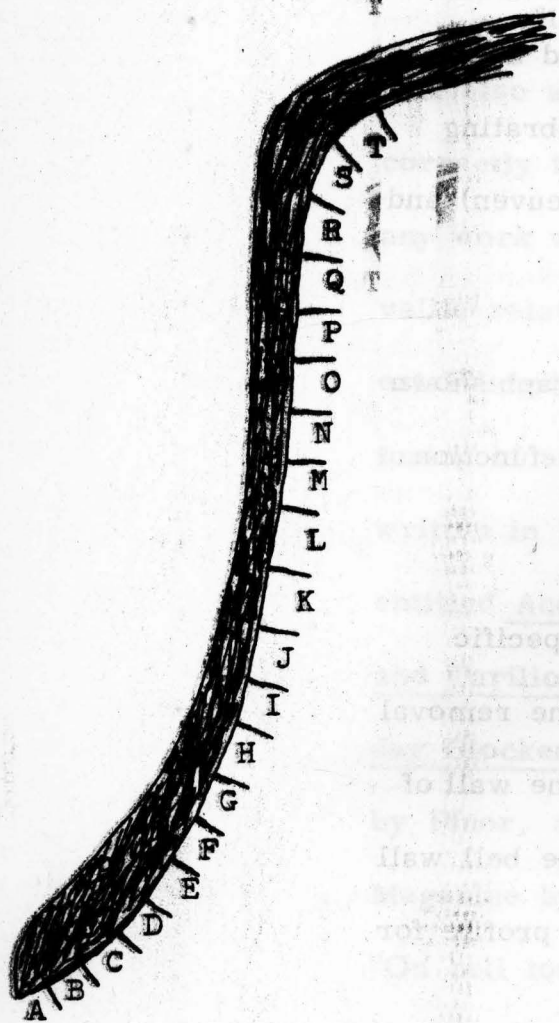
Van Heuven also wrote about the measuring of overtone frequencies by using modern electronic equipment. This is a significant improvement since adjustable tuning forks are less accurate. Using these electronic and precise measuring apparatuses, the bellfounder can now tune an overtone to an accuracy of a few cents (1 cent is 1/100th of a

semitone). The overtones are isolated and abstracted from the bell by using a vibrating needle (named the "exciter" by Van Heuven) and then measured with a tone-generator.

André Lehr has drawn the graph shown on the following page, illustrating the function of the tuning locations on a bell.

Tuning is the function of a specific frequency change of an overtone by the removal of a specific amount of metal from the wall of the bell. As the tuning proceeds, the bell wall becomes thinner until it is the exact profile for an accurately tuned bell.

Beginning at the lip, the inner profile is divided into equal sections, each $1/25$ th the diameter of the bell. Each section is identified with a letter (A, B, C, etc.), shown in the sketch of the profile on André Lehr's graph. By using this graph it is easy to see that certain places on the bell are more sensitive to lathing than others. For instance, in sections A and B,



the hum-tone raises sharply, while between sections C and E it will lower. From E to P, lathing of the bell will have gradually less effect on the hum-tone. The hum-tone is not affected with lathing between Q to T, for these sections are in the upper waist and shoulder of the bell. Thus, if the hum-tone is to be lowered, lathing should be performed on one or more sections between D and O. If the hum-tone is lowered by lathing between sections E and F, it can readily be seen that the other overtones will also be lowered. If, for example, the hum-tone needed to be lowered only slightly and was accomplished by lathing between N and O, the resulting effects on the other overtones would be: the fundamental would rise; the minor third would remain unchanged, the fifth would be lowered, and the nominal would rise at N but lower at O. In order to observe the effects of lathing at a certain section, all five sections of the graph must be read simultaneously. The bell tuner must be well versed in the science of acoustics, be well acquainted with the harmonic

structure of a bell, and have a good sense of judgement and hearing.

Here is another example of how the graph works. If the fifth needs to be lowered a great deal and the fundamental is already too high (while the other overtones need not be affected in any way), lathing may be performed between P and R.

The situation becomes more difficult if the overtones must be tuned a great deal, as shown on the following graph. This graph uses as an example a b-flat¹ bell having a diameter of 86 cm. and a weight of 427 kg. before tuning. The upper part of the graph names the overtones and their place in relation to each other in cents, while the lower part shows the deviation and steps used for its correction.

	Hum-tone	Fundamental	Minor Third	Fifth	Nominal
Lathing between	b-flat 44	b-flat ¹ 48	d-flat ² 34	f ² 56	b-flat ² 26
C - T	24	40	20	56	14
D - T	6	34	10	13	6
D - F	4	29	8	10	2
E - G	0	27	6	8	0
Q - S	0	11	5	4	0
S - T	0	0	4	1	0

Thus none of the overtones need be raised, but only lowered, and the tuning of the lip is not necessary. The first lathing should cover the entire inner surface of the bell, as in the example above from C - T. The same is true for the second lathing but this time beginning at D. After these two procedures, the desired pitch is almost reached. However, the nominal is still six cents off its desired pitch and, hence, also the strike-note. Now the tuning function is aimed at the other overtones. By lathing between D and F, all of the tones will lower a certain degree. The fourth lathing, from E - G, causes the hum-tone and the nominal to sound at the desired pitch.

The fifth lathing, from Q - S, does not affect the hum-tone or fundamental, but lowers the other overtones. The sixth and final lathing, between S and T, causes the bell to be correctly tuned. A slight deviation of the minor third and fifth is to be expected. A total of nine kilograms of bell bronze has been removed by this process of tuning.

The procedures outlined above and the desired intervallic relationship of the overtones of the tuned bell have been well planned before the casting of the bell. In practice, the bell-founder tries to cast a bell which has the same characteristics as the one mentioned above, i.e., the fundamental too high and the fifth even higher. This can be accomplished by manipulating the molds to alter the profile. It is important that the fifth is high, for, as can be seen on the graph, it will constantly lower as the bell is lathed.

The tuning of a bell higher (sharp) is hardly possible and can only be accomplished when the fifth is extremely high. The raising of the

hum-tone and fundamental is primarily done by lathing the lip between A and B, as seen in the graph, and then only within the range of 10 cents. If much lathing is performed on the lip, it will slightly alter the overall proportion of the bell and will unfavorably influence its composite sound.

Suggestions for tuning a bell:

- 1) Never lathe a bell to such an extent that it destroys the proportion between the thickness of the wall and the bell weight.
- 2) The hum-tone can rarely be tuned higher, and when possible, only upwards to 10 cents.
- 3) The fundamental will rise a maximum of 10 cents, but never by lathing at the waist.
- 4) The nominal will rise only 20 cents.
- 5) As a rule, the nominal can be lowered only 50 cents.
- 6) The fifth can never be raised.
- 7) The minor third is not tuned as an individual overtone. Its tuning is the function of lathing for other overtones.

As the graph indicates, it is possible to remove considerable material between R and T and not affect the timbre of the bell. It often improves the acoustical damping of other overtones.

The proper techniques for the correct tuning of bells were first discovered in the seventeenth century. This was made possible by understanding and experimenting with the harmonic structure of a bell. The beautifully tuned carillons of the Hemony brothers, who were greatly assisted by Jhr. Jacob Van Eijck, is indicative of this fact.

The Hemonys and their predecessors tuned a bell by removing material from the inner surface of the bell with files and grindstones.³ For large bells a chisel was used. If the pitch of the bell had to be raised, they would tune the lip, and if it had to be lowered, material was removed from the sound-bow. This technique was also employed for tuning other idiophones and some pre-Hemony carillons. Generally speaking, the art of bell-founding and tuning was lost after the Hemony era.

Pfnor and the Reverend Simpson were responsible for rediscovering the proper techniques for tuning a bell. Their experimentations and discoveries have been a benefit for all mankind, for today, beautifully tuned bells are available and widely enjoyed by many cultures.

When tuning a bell, the lathing generates friction heat⁴ for which compensation must be made. Otherwise, a pitch deviation of five cents may occur.

A bell is very sensitive to temperature and therefore, in order to get the correct balance between its pitch and its normal temperature, it must not be allowed to cool too quickly after its casting.⁵ When this occurs, a bell could, after a period of time, sound lower than desired. To prevent this, a newly cast bell must be allowed to cool slowly.

The acoustical phenomenon which results from the interference of two or more sound waves of slightly different frequencies is commonly called

'beats' and, as much as possible, must be eliminated from the bell during its tuning. A fast beat in a bell can be very irritating while a slow beat, being less disturbing, can actually add warmth and texture to the bell sound. Some carillon enthusiasts have even said that a slow beat adds considerable charm, just as the never perfectly tuned pipe organ is considerably more pleasant than the mathematically correct tuning of an electric organ.⁶

A beat will occur when two tones have the same pitch but a slight difference in frequency. For example, if the strike-note of an a^1 bell is 440 Hz., while the nominal of a bell an octave lower is 435 Hz., the resulting beat will have a frequency of 5 Hz. Therefore, within one second, the inaccurately tuned tones will cause the composite bell sound to fluctuate five times between the maximum and minimum intensities: in other words, five beats per second. It is possible to have beats between the strike-notes of two belis, between the intervallic relationships of the harmonic structure within one bell, or between the

overtones of two bells. For example, if the fundamental and nominal within one bell is not correctly tuned to the exact interval of one octave, beats will be noticeable.⁷ Another example is when the minor third harmonic of a c^1 bell is incorrectly tuned and sounded together with an e-flat¹ bell. Needless to say, the art of tuning bells is a highly refined science which demands much patience and care.

Beats will also occur if the profile is not perfectly symmetrical, i.e., if one section of the circumference of the bell is thicker. This is also true if the composition of the bell bronze is not homogeneous⁸ at any given place on the bell, i.e., if one place is more porous. The result of both of these defects in the casting process will be unpleasant beats caused by the formation of two hum-tones, two nominals, etc., each having a different frequency. The unpleasant beats in such a bell can usually be eliminated if the correct striking place on the bell is found. This is similar to the hum-tone being adversely

affected if struck on an antinode.⁹ If the profile of a bell is perfectly symmetrical, the same results will occur by striking the bell anyplace around its circumference. This is not true, however, if a certain place on the bell is too thick or porous. Experimentation has proved that the nodes and antinodes around a bell are positioned by any defect in the profile or casting process.

If two hum-tones result from a faulty profile or casting, one hum-tone will have only one node because the other hum-tone has an antinode through the section of the bell which is too thick or porous. If the bell is struck at any place other than this one node, unpleasant beats between the two hum-tones will occur. When the bell is struck where the defect occurs, the upper hum-tone will sound most prominent, for the lower hum-tone will have only one node. A search must then be undertaken to find the correct place on the bell which, when struck, will allow both hum-tones to sound. Usually a

nodal point of the upper hum-tone will also sound the lower hum-tone. Theoretically, there are eight places around the bell which allow both hum-tones to speak: the four nodes for both hum-tones. As stated above, the best results usually occur when the bell is struck on one of the four nodes of the upper hum-tone.

This is just one method used to keep the bell free of beats. It would be better, however, to correct these faults during the tuning process. The symmetry (profile) of the bell can be corrected by removing the proper amount of material from specific places inside the bell. This is usually accomplished with vertical grooves which will eliminate the beats.

¹ Translator's note: An untouched, untuned bell.

² Author's note: The first set of tuned bells, using the tuning methods rediscovered by the Reverend Simpson, were sent to Iowa State University in Ames, Iowa.

³ Translator's note: Francois Hemony used tuned metal bars for tuning his bells. He placed the metal bars on a bed of sand and sprinkled a few grains of sand on the top of the bar. When the overtone of a bell was equal to the frequency of the metal bar, sympathetic vibrations caused the bar to sound, which, in turn, caused the grains of sand on the bar to become agitated. When the grains jumped around, he knew that the particular overtone was correct in relation to the metal bar.

⁴ Translator's note: Before the bell is checked for correct tuning, it must cool to room temperature. This increases the time necessary for tuning a bell but ensures a finer result.

⁵ Translator's note: Earlier, hot embers were buried in the ground surrounding the newly cast bell so that it would not cool too rapidly. A quick cooling of a bell can cause the bronze to crystallize or become porous.

⁶ Author's note: Another example of an obvious charm by a slight occurrence of beats is the string orchestra, where each performer can not be accurately in tune with each other.

⁷ Translator's note: Since the strike-note is a resultant of the nominal, an inaccuracy in the tuning of the nominal is very noticeable. When this occurs the pitch of the bell changes, for the strike-note loses its intensity rapidly and is quickly replaced by the fundamental and hum-tone, causing the pitch to rise to the pitch of the fundamental.

⁸ Translator's note: Often caused by improper casting techniques or a too rapid cooling of the bell.

⁹ Translator's note: See Chapter XX.

CHAPTER XXIII

CLAPPERS

A proper clapper is very important, for different clappers bring out different sounds from a bell. In delineating the correct clapper for a bell, the following four factors must be discussed:

- A. The weight of the clapper
- B. The velocity at which the clapper strikes the bell
- C. The material of the clapper
- D. The shape of the clapper

A. The weight of the clapper

A bell sounds warmer and is more sonorous when struck by a relatively heavy clapper. When struck by a clapper that is too light, the same bell will sound cold and defeated. A heavy clapper brings the hum-tone prominent while a light clapper emphasizes the upper harmonics.

Although preference plays an important role in the choice of clapper weights, the following proportions of bell and clapper weights are most often used:

Clapper for a swinging bell -- 3% to 5%
the bell weight.

Clapper for a carillon bell -- large bells
have clappers which weigh approximately 1% of the bell weight,
graduating to 10% for small bells.

Large bells may be made to sound very full and warm if a somewhat heavy clapper is attached.

B. The velocity at which the clapper strikes the bell

A short, intense strike brings out more of the harmonic structure of a bell than does a more gentle strike. Equally as important as the energy transfer to the bell is the contact time between the bell and the clapper. A longer contact time will muffle the higher overtones. The duration of the contact between bell and clapper is in the range of 1/10 to 1/100 of a second.

C. The material of the clapper

A soft material causes the contact time to be longer and hence brings out the lower overtones. Exaggerated examples are soft clappers made of lead or plastic,¹ etc., and hard clappers made of iron which cause the bell to sound poorly. The most common material for clappers today is manganese-brass.² Because it is slightly softer than the bell bronze, the manganese-brass clapper will suffer the damage after extended use, thus sparing the bell. Manganese-brass is an alloy of 40% zinc, 1% manganese, 1% tin, 1% aluminum, and 57% copper. Bronze (copper and tin) is somewhat harder than brass (copper and zinc).

D. The shape of the clapper

The most desirable and commonly used shape is the sphere.³ The sphere contacts the bell only in a small area, which is important for the sound of the bell. The symmetrical shape of the sphere is not likely to be reflected into sideways motion.

Until a few years ago a cylindrical clapper, with a tapered lead point, was very popular. However, extended use causes this tapered point to flatten and the contact surface between clapper and bell becomes too large.

¹ Author's note: This is purely theoretical and has never been actually used.

² Translator's note: This has also been called manganese-bronze, but the composition of the alloy is closer to brass than bronze.

³ Translator's note: It is sometimes described as ball or globe.

CHAPTER XXIV

ACOUSTICS AND TEMPERAMENTS¹

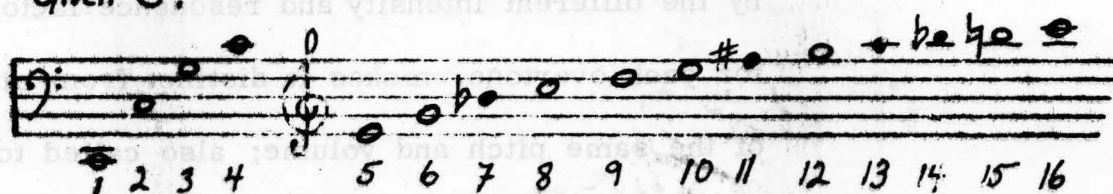
Definitions

- 1) Acoustics -- the science of sound.
- 2) Temperaments -- tuning systems having varied interval deviations.
- 3) Sound -- a vibratory disturbance having an audible frequency range of c. 20 to 20,000 cycles per second.²
- 4) Vibration -- a rapid, elastic movement back and forth.
- 5) Amplitude -- maximum width of vibration.
- 6) Periodic vibrations -- every alternate vibration has a greater amplitude.
- 7) Tone -- a sound having a distinct pitch, timbre, and duration.
- 8) Timbre -- the quality or complexion of a tone which, by the different intensity and resonance factors for each overtone, makes it distinct from others of the same pitch and volume; also called tone color.

- 9) Noise -- a sound comprised of nonharmonic overtones which has no distinct frequency (pitch).
- 10) Speed of sound -- approximately 340 meters per second, faster at higher temperatures and slower at lower temperatures.
- 11) Tone properties:
- a) pitch -- subjective quality of a composite sound determined by the frequency (number of vibrations per second) of the sound.³
 - b) intensity -- strength of tone as determined by the amplitude of the vibrations.
 - c) duration -- timed continuance of tone (vibration).
 - d) timbre -- (see above).
- 12) Harmonics⁴ -- pure tones embodied in a composite sound, having fixed intervallic proportions to the fundamental in harmonic sound producers.⁵

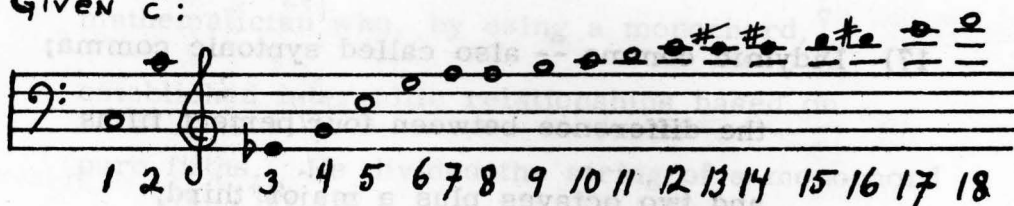
Given C:

Harmonic structure of a string:



Harmonic structure of a tuned bell:

Given c^1 :



ALL NOTES
SHOULD BE
WHITE.

(See Chapter XX.)

The numbers below the notes indicate the intervallic and vibration ratios between

the harmonics, e.g., nominal 2:1, fifth

3:2, etc. The harmonic structure of a

string, respective to the vibrations, can

be shown as 1:2, 1:3, 1:4, etc.

13) Cents -- the logarithmic⁶ unit of a scientific

and exact method of measuring musical

intervals. One cent equals 1/1200th

octave, hence 100 cents is a semitone in

the equal temperament.

14) Millioctave -- abbr. mo. There are 1000 mo.

in an octave, hence, 1 mo. = $\frac{6}{5}$ cents.

100 cents = approximately 83 mo.

15) External tuning -- tuning of bells to interval

related proportions, each to the other.

- 16) Internal tuning -- tuning overtones of one bell to a harmonic structure.
- 17) Didymic comma -- also called syntonic comma; the difference between four perfect fifths and two octaves plus a major third; applied in just temperament as the difference between two major or minor whole tones.
- 18) Limma -- Pythagorean semitone.
- 19) Apotome -- difference between Pythagorean whole tone and semitone.
- 20) Pythagorean comma -- also called ditonic comma; the difference between twelve perfect fifths and seven octaves -- better referred to as the difference between Limma and Apotome (approximately 24 cents) and between perfect fifth and 'wolf' quint of Pythagorean temperament.

Temperaments (Scales)

A temperament is a system of tuning in which the intervals deviate within the perfect (natural) octave, i.e., a system of different intervallic relationships forming a scale.

Pythagoras (c. 550 B. C.) was a Greek mathematician who, by using a monochord,⁷ established intervallic relationships based on pure fifths. He divided the string of a monochord into the following ratios:

3rds ($\frac{1}{3}$ $\frac{2}{3}$) ratio 1:2 = perfect octave

5ths ($\frac{2}{5}$ $\frac{3}{5}$) ratio 2:3 = perfect fifth

7ths ($\frac{3}{7}$ $\frac{4}{7}$) ratio 3:4 = perfect fourth

Once establishing these ratios, Pythagoras calculated the remaining intervals. (See Chapter XXV.)

Arnold Schlick wrote Spiegel der Orgelmacher und Organisten in 1511, in which he specified the mean-tone scale (tuning). Using the Didymic comma of the just temperament, he divided four fifths. The name mean-tone (middle-tone) was used because the whole tone intervals are aliquot parts of the major and minor whole tones of the perfect tuning. Thus, the d is halfway between c and e, the g is halfway between f and a, and the a halfway between g and b. Consequently, the fifths cannot be perfect, but have a smaller intervallic proportion. (See Chapter XXV.)

3rds ($\frac{1}{3}$ $\frac{2}{3}$) ratio 1:2 = perfect octave

5ths ($\frac{2}{5}$ $\frac{3}{5}$) ratio 2:3 = perfect fifth

7ths ($\frac{3}{7}$ $\frac{4}{7}$) ratio 3:4 = perfect fourth

9ths ($\frac{4}{9}$ $\frac{5}{9}$) ratio 4:5 = major third

11ths ($\frac{5}{11}$ $\frac{6}{11}$) ratio 5:6 = minor third

c - e-flat - e - f - g - c

$$1/1 \quad 6/5 \quad 5/4 \quad 4/3 \quad 3/2 \quad 2/1$$

c - d - e - f - g - a - b - c

1/1 9/8 5/4 4/3 3/2 5/3 15/8 2/1 times the no.
of vibrations

d - e (equal to the difference between the major third c - e and the major second c - d) can be

calculated in the following manner:

$$d - e = 5/4 \div 9/8 = 5/4 \times 8/9 = 40/36 = 10/9.$$

By using this same procedure, the remaining ratios can be found:

$$\begin{array}{cccccccc} c & - & d & - & e & - & f & - & g & - & a & - & b & - & c \\ 9/8 & & 10/9 & & 16/15 & & 9/8 & & 10/9 & & 9/8 & & 16/15 \end{array}$$

Thus, the major whole step is $9/8$ and the minor whole step is $10/9$, and their ratio is

$$9/8 \div 10/9 = 9/8 \times 9/10 = 81/80,$$

being the syntonic or Didymic comma.

The just intonation, although having disadvantages, offers greater possibilities for a 12 note per octave instrument than the Pythagorean tuning.

Zarlino, in his Dimostrazione harmoniche (1571), described a keyboard instrument that was tuned to the just intonation and stated that all fifths must remain in a quarter comma and all major thirds are to be perfect, thus eliminating beats.

The following series is the mean-tone scale:
c, c-sharp, d, e-flat, e, f, f-sharp, g, g-sharp, a,
b-flat, b, c, etc. There are five chromatic (major)
semitones of 114 cents (c - c-sharp, e-flat - e,
f - f-sharp, g - g-sharp, b-flat - b) and seven
diatonic (minor) semitones of 90 cents (c-sharp - d,
d - e-flat, e - f, f-sharp - g, g-sharp - a,
a - b-flat, and b - c).

In Van de Spiegelingh der Singhconst (1611)
Simon Stevin of Bruges proposed an equal tuning which
divided the octave into 12 identical semitones. By
doing this only the octave remains perfect while all
other intervals deviate slightly.

The practical application of the equal tuning
proposed by Stevin was put forth in Von der Musikalischen
Temperatur (1691) by Andreas Werckmeister: all octaves
are perfect, all fifths and thirds major. The intervallic
relationships of the fifths are somewhat less than with
just intonation, while the thirds are between the
Pythagorean thirds and the just intonation thirds. The
Pythagorean comma equally divides the interval of a

fifth in the 'circle of fifths', causing the equal temperament to be readily applicable. J.S. Bach wrote his 48 preludes and fugues of The Well-Tempered Clavier for this temperament.

Before closing a chapter concerning temperaments or scales, Christian Huygens must be mentioned. In 1661 he calculated a temperament which divided the octave into 31 identical parts with each microtone equaling $1/5$ th semitone and having the frequency of $1200 \div 31 = 38.7$ cents. His findings were published under the title of Cycle Harmonique. This unequal temperament is actually merely a refinement of the mean-tone scale. Any instrument having 31 tones per octave demands that it be a keyboard instrument. There is an organ in the Teylers Museum in Haarlem which has been tuned to the scale as proposed by Huygens. It has 31 keys (notes) per octave. By drawing stops the organist is capable of choosing the tones of the octave he desires to use, thus changing the temperament (scaling). He can thus experiment and design new temperaments.

The large custom-made keyboard is so constructed that all 31 tones per octave can be played. The keys are small (38 x 11 mm.) and do not pivot like an ordinary key but depress vertically like a button, having a depression depth of 5 mm. The keys are color coded indicating the tone they play. White keys are the diatonic scale of c, d, e, f, g, a, b, c, etc., while the black keys play c-sharp, d-flat, d-sharp, e-flat, etc., and blue keys play c-, d-, d-, e-, etc.

The pedal also has 31 notes per octave with a range of 1-1/2 octaves (45 pedals). The registration is Quintadena 8', Prestant 4', Salicional 8', Rohrflute 4', and Subbass 16'.

¹ Translator's note: For a better understanding of temperaments, acoustics, and intervallic deviations which form the various scales, see the Harvard Dictionary of Music.

² Author's note: Overtones having frequencies above 5,000 cycles per second are unimportant for the accurate tuning of a bell.

³ Author's note: The a¹ (above middle c) has 440 cycles per second (440 Hz.).

⁴ Author's note: Often referred to as overtones, partials, or natural tones.

⁵ Translator's note: "The harmonic of lowest frequency is called the fundamental, and because it is louder than the others it determines the pitch of the composite tone." [Willi Apel, Harvard Dictionary of Music (Cambridge, Massachusetts, 1970), p. 10.]. This is true for all harmonic sound producers except the tuned bell. The first overtone of a tuned bell is the minor third. The fundamental and hum-tone are referred to as harmonics. The tone which determines the pitch of a bell is called the strike-note and is an octave resultant of the nominal, although the strike-note and the fundamental sound the same tone in an accurately tuned bell.

⁶ Author's note: An oversimplification of the definition of logarithms is: multiplication and division reduced to the function of simple addition and subtraction.

Translator's note: A thorough understanding of logarithms is important for a comprehensive study of bells (Campanology).

⁷ "A device consisting of a single string stretched over a long wooden resonator to which a movable bridge is attached so that the vibrating length of the string can be varied." [Willi Apel, Harvard Dictionary of Music (Cambridge, Massachusetts, 1970), p. 537.].

CHAPTER XXV

TEMPERAMENT CALCULATIONS

A temperament is based on the fact that thirds, fifths, and octaves are important tones for harmony. A perfect third (e. g., c - e) sounds beautiful because of the tonal agreement between the fourth harmonic of the e and the fifth harmonic of the c. When they sound the same tone, as they should in a well tuned bell, there are no ensuing beats. For the perfect fifth (e. g., c - g), there is harmonic agreement between the second harmonic of the g and the third harmonic of the c.

For the sake of convenience the equal temperament will be used in the following calculations. All semitones are equal in size, namely 100 cents. The semitone progression is:

c	-	c-sharp	-	d	-	d-sharp	-	e	-	f	-	f-sharp	-
0		100		200		300		400		500		600	
g	-	g-sharp	-	a	-	a-sharp	-	b	-	c,	etc.		
700		800		900		1000		1100		1200			

The basis for the equal temperament is perfect thirds (at 386 cents) and perfect fifths (at 702 cents).

A. Pythagorean scale

The basis of the Pythagorean scale is perfect octaves and perfect fifths. By progressing up the tone ladder in perfect fifths twelve times we have:
c - g - d¹ - a¹ - e² - b² - f-sharp³ - c-sharp⁴ - g-sharp⁴
- d-sharp⁵ - a-sharp⁵ - e-sharp⁶ - b-sharp⁶, until,
after seven octaves, there is an interval of c - b-sharp
having a tone ratio of $(3/2)^{12} \div 2^7 = 1.0136$, being
somewhat too large.

It is possible to arrive at these fifths in another manner, i.e., an upper progression from c until g-sharp, and extending downward until e-flat.

The result is: E-flat - B-flat - f - c¹ - g¹ - d² - a² -
e³ - b³ - f-sharp⁴ - c-sharp⁵ - g-sharp⁵. By extending
the upward progression of these fifths, there would be
a d-sharp which would not be an e-flat (see b-sharp -
c relation above). In this last example there is now
formed a fifth (g-sharp - e-flat) which is too small
and therefore unusable. It is for this reason that

only the key signatures from A (three sharps) through C to B-flat (two flats), and their respective minors, can be used when an instrument is tuned with the Pythagorean scale.

The most noticeable characteristics of the Pythagorean tuning are:

1. all major seconds are identical.
2. the major thirds are larger (408 cents) than those of the just intonation and the equal temperament.
3. the same is true of major sixths.
4. the minor thirds are smaller than those of the aforementioned temperaments.
5. likewise the minor sixth is smaller.
6. the 'diatonic' semitone (Limma) is smaller than those of the aforementioned temperaments.
7. the 'chromatic' semitone (Apotome) is larger than those of the aforementioned temperaments.

The difference between the Limma and the Apotome is called the Pythagorean comma. Two important facts should be remembered about the Pythagorean temperament:

- 1) major and minor triads do not sound well due to the dissonant character of the thirds and sixths.
- 2) the semitones are not identical.

The following is a calculation of the Pythagorean scales in cents. The fifth is 702 cents, being 2 cents higher than the equal temperament fifth. If, for example, they were to be raised 2 cents, the successive fifths would each have to be raised an additional 2 cents (i.e., plus 2, plus 4, plus 6, etc.) to retain the same proportion. If the fifths were lowered 2 cents for each intervallic succession (i.e., minus 2, minus 4, minus 6), they would be of the same proportion as the fifths in the equal temperament. (See Chapter XXVI, Table I.)

When playing a carillon in the Pythagorean temperament, extreme care must be given to the d-sharp - e-flat, f-sharp - g-flat, etc., for they are always 24 cents. The microtonal difference (approximately $1/4$ semitone) is noticeable and, therefore, a d-sharp can never be substituted for an e-flat.

B. Mean-tone system

The mean-tone scale is based on perfect (major) thirds and perfect octaves.

By advancing up the tone ladder by fifths four times, the perfect third for the fundamental of the first fifth is found. For example, c - g, g - d, d - a, a - e. If the fifths were made perfect, the thirds would be too high and imperfect. As stated before, the thirds of the Pythagorean tuning are 408 cents (see Chapter XXVI), while perfect thirds are 386 cents. Thus, the difference is 22 cents which can be divided into the four fifths: $22 \div 4 = 5\text{-}1/2$. Using the perfect fifths as a starting point, the mean-tone scale can be calculated by removing from each progressive fifth an additional $5\text{-}1/2$ cents, i.e., minus $5\text{-}1/2$, 11, $16\text{-}1/2$, etc. Thus, progressive fifths of the mean-tone scale become smaller or larger, depending on the direction taken. (See Chapter XXVI, Table I.)

The mean-tone temperament is diagrammed below. The vertical columns contain the perfect

thirds while the horizontal rows contain the mean-tone fifths.

g-sharp

e	-	b	-	f-sharp	-	c-sharp	-	g-sharp
c	-	g	-	d	-	a	-	e
		e-flat	-	b-flat	-	f	-	c

The characteristics of the mean-tone scale are:

- 1) The last fifth, g-sharp - e-flat, is much too large (738 cents).
- 2) The last thirds in the progression around the circle of fifths are likewise too large and cannot be used: b - e-flat, f-sharp - b-flat, c-sharp - f, and g-sharp - c (in actuality, b - d-sharp, f-sharp - a-sharp, c-sharp - e-sharp, and g-sharp - b-sharp).

As in the Pythagorean temperament, the performer is again limited to key signatures from three sharps to two flats. Therefore, the minor keys which also can be used are:

a minor, harmonic and melodic

(f-sharp and g-sharp are present)

d minor, harmonic and melodic

(b-flat, b and c-sharp are present)

g minor, harmonic and melodic

(e-flat, e and f-sharp are present)

C. Modified Mean-tone systems

The ever increasing demand for more or different usable chromatics has also manifested itself for keyboard instruments having 12 tones per octave. For this need a number of modified mean-tone systems have resulted and are compared in Chapter XXVI.

D. Equal temperament

The equal temperament is credited to Andreas Werckmeister (c. 1700), but there is evidence to prove that the idea of dividing an octave into twelve identical parts is much older. Earlier this identical intervallic scale was called Parallel Beats Temperament, but Professor A. D. Fokker took exception to this on the grounds that the fifth $c^2 - g^2$ has, in this tempered scale,

only one beat per second, the fifth $c^3 - g^3$ (proportionately doubling the vibrations) has almost two beats per second, while the lower fifth $c^1 - g^1$ has only $1/2$ beat per second.

The advantages of the equal temperament are:

- 1) it is musical with the use of all key signatures,
- 2) modulation is possible to any key,
- 3) there are unlimited possibilities for nonharmonic transpositions.

A disadvantage is that all intervals, except the octave, are inaccurately pitched due to the microtonal compromise necessary. In comparison with the just intonation, intervals which are too large are the major third, perfect fourth, major sixth, and the major or minor seventh. Those that are too small are the major and minor second, minor third, perfect fifth, and the minor sixth.

In comparison with the Pythagorean temperament, intervals that are too large are the minor second and third, perfect fourth, minor sixth and seventh. Those too small are the major second and third, perfect fifth, major sixth and seventh.

CHAPTER XXVI

CALCULATION SYNOPSIS

The basis for the equal temperament is the division of the octave (1200 cents) into equal semitones:

c	-	c-sharp (d-flat)	-	d	-	d-sharp (e-flat)	
0		100		200		300	
-	e	-	f	-	f-sharp (g-flat)	- g -	
	400		500		600		700
	g-sharp (a-flat)	-	a	-	a-sharp (b-flat)	-	
	800		900		1000		
			b	-	c.		
			1100		1200		

The following chart further delineates the cent ratios between the equal, Pythagorean, and mean-tone temperaments. Note that while progressing in fifths, the Pythagorean alters 2 cents from the equal while the mean-tone alters 5-1/2 cents from the Pythagorean.

TABLE I:

<u>Tone</u>	<u>Equal Temperament</u>	<u>Pythagorean Temperament</u>	<u>Mean-Tone Temperament</u>
g-flat	600	-12 = 588	588 + 33 = 621
d-flat	100	-10 = 90	90 + 27-1/2 = 117-1/2
a-flat	800	-8 = 792	792 + 22 = 814
e-flat	300	-6 = 294	294 + 16-1/2 = 310-1/2
b-flat	1000	-4 = 996	996 + 11 = 1007
f	500	-2 = 498	498 + 5-1/2 = 503-1/2
c	0	-0 = 0	0 + 0 = 0
g	700	+2 = 702	702 - 5-1/2 = 696-1/2
d	200	+4 = 204	204 - 11 = 193
a	900	+6 = 906	906 - 16-1/2 = 889-1/2
e	400	+8 = 408	408 - 22 = 386
b	1100	+10 = 1110	1110 - 27-1/2 = 1082-1/2
f-sharp	600	+12 = 612	612 - 33 = 579
c-sharp	100	+14 = 114	114 - 39-1/2 = 75-1/2
g-sharp	800	+16 = 816	816 - 44 = 772
d-sharp	300	+18 = 318	318 - 49-1/2 = 268-1/2
a-sharp	1000	+20 = 1020	1020 - 55 = 965

The following table makes a comparison of the cent temperaments. Note the deviations of the chromatics.

TABLE II:

Pitch:	c	c-sharp	d-flat	d	d-sharp
Equal	0	100	100	200	300
Pythagorean	0	114	90	204	318
Mean-tone	0	75-1/2	117-1/2	193	268-1/2
	e-flat	e	f	f-sharp	g-flat
	300	400	500	600	600
	294	408	498	610	588
	310-1/2	386	503-1/2	579	612
	g	g-sharp	a-flat	a	
	700	800	800	900	
	702	816	792	906	
	696-1/2	772	814	889-1/2	
	a-sharp	b-flat	b		
	1000	1000	1100		
	1020	996	1100		
	965	1007	1082-1/2		

The thirds which are usable with the mean-tone temperament are those having an interval of 386 cents. For example, $d - f\text{-sharp} = 579 - 193 = 386$ cents. The thirds which can not be used are those having an interval of 428 cents. For example, $f\text{-sharp} - b\text{-flat} = 1107 - 579 = 428$ cents.

When playing on a carillon tuned with the mean-tone temperament, care must be given that only the following thirds are used: $c - e$, $d - f\text{-sharp}$, $e\text{-flat} - g$, $e - g\text{-sharp}$, $f - a$, $g - b$, $a - c\text{-sharp}$, $b\text{-flat} - d$.

The tone ladder of the mean-tone temperament is as follows:¹ $c - c\text{-sharp} - d - e\text{-flat} - e - f - f\text{-sharp} - g - g\text{-sharp}$ ² $- a - b\text{-flat} - b - c$.

It is important to remember the following summary:

Perfect thirds = 386 cents

Perfect fifths = 702 cents

Pythagorean thirds = 408 cents

Mean-tone fifths = $696\frac{1}{2}$ cents

Pythagorean: all fifths and octaves are perfect,
all major seconds are identical
intervals; all other intervals are
altered, i.e., major intervals are
larger while minor intervals are
smaller.

Mean-tone: all thirds and octaves are perfect;
the other intervals are also altered
but in reverse from the Pythagorean,
i.e., major intervals are smaller
and minor intervals are larger.

Summary of the different temperaments in cents:

perfect fifths = 702

perfect thirds = 386.4

perfect (minor) sevenths = 969

1. Equal temperament
2. Just intonation
3. Pythagorean temperament
4. Mean-tone, Arnold Schlick (1511)
5. Mean-tone, Gioseffo Zarlino (1558)

6. G. Silbermann, organ builder (1683-1753)
7. Modified Mean-tone temperament
(University organ, Salamanca, Spain)
8. Modified Mean-tone temperament
9. Modified Mean-tone, J. Kirnberger (1721-1783)
10. Provisional temperament, progenitor to the
equal temperament
11. Andreas Werckmeister (1691),
J.G. Reinhardt (1706)

(Decimals have been omitted from the following graph.)

	c	c#	db	d	d#	eb	e	f	f#	gb	g	g#	ab	a	a#	bb	b
1.	0	100	100	200	300	300	400	500	600	600	700	800	800	900	1000	1000	1100
2.	0	71		204		315	386	498	568		702	872	813	884		1017	1088
3.	0	114	90	204	318	294	408	498	612	588	702	816	792	906	1020	996	1110
4.	0	76		193		310	386	503	579		696	772		889		1006	1083
5.	0	70		192		312	382	504	574		696	766	793	888		1008	1060
6.	0	85		195		306	392	501	588		697	783		894		1004	1094
7.	0	86		196		306	392	501	589		698	784		894		1004	1090
8.	0	93		193		292	386	500	600		699	793		886		1006	1086
9.	0		90	204		294	386	498	588		702		792	906		996	1088
10.	0	92		200		292	399	507	600		708	800		900		999	1100
11.	0	99	99	200	300	300	399	500	600	600	699	800	800	900	999	999	1100

Comments on the aforementioned temperaments:

Mean-tone, Arnold Schlick (1511): eight perfect

thirds; c - e, d - f-sharp, e-flat - g,

e - g-sharp, f - a, g - b, a - c-sharp,

b - d. Four thirds of 427.2 cents which

are too large and, therefore, unusable:

c-sharp - f, g-sharp - c, b - e-flat,

f-sharp - b-flat. These unusable thirds

are only 19 cents larger than in the

Pythagorean temperament. The

wolf quint³ is very large, 748 cents,

46 cents larger than the perfect fifth.

Modified Mean-tone temperament in Salamanca, Spain:

eight thirds of 392.4 cents which are quite

usable, four thirds of 415.2 cents which

are somewhat too large but still usable.

The fifths are 698.4 cents and usable while

the wolf quint is 721.2 and can not be used.

Modified Mean-tone temperament: four perfect

thirds of 386.4 cents: c - e, g - b,

b-flat - d, f - a. Eight unusable thirds of

406.8 cents: a - c-sharp, c-sharp - f,
e - g-sharp, g-sharp - c, e-flat - g,
b - e-flat, d - f-sharp, f-sharp - b-flat.

Six very usable fifths of 699.6 cents:

c - g, e - b, g-sharp - e-flat, f - c,

a - e, c-sharp - g-sharp. Four usable

fifths of 693.6 cents: b-flat - f, d - a,

f-sharp - c-sharp, g - d, and two barely

usable fifths of 714 cents: b - f-sharp,

and e-flat - b-flat.

Provisional system: four usable thirds of 392.4

cents: g - b, b - d-sharp, f - a, and

a - c-sharp. Six usable thirds of 399.6

cents: b-flat - d, d - f-sharp, f-sharp -

b-flat, c - e, e - g-sharp, g-sharp - c.

Two barely usable thirds of 415.2 cents:

c-sharp - f and d-sharp - g. Four very

usable fifths of 692.4 cents: f - c,

g-sharp - d-sharp, f-sharp - c-sharp,

g - d. Four very usable fifths of 699.6

cents: a - e, e - b, b - f-sharp, d - a,

and four additional usable fifths of 708

cents: c - g, d-sharp - b-flat,

b-flat - f, and c-sharp - g-sharp.

¹ Translator's note: Since the mean-tone temperament has a c-sharp and not a d-flat, care must be given so that the c-sharp is never used when a d-flat is intended. This is true for the other chromatics as well, e.g., never use b-flat for a-sharp.

² Translator's note: On certain carillons which have a modified mean-tone temperament, the g-sharp has been traded for an a-flat.

³ Translator's note: The wolf quint is a result of imperfect tuning. However, when referring to unequal temperaments or scales, it means the last fifth in the progression of fifths, which is usually too large.

CHAPTER XXVII

DEVIATION IN THE DISTRIBUTION OF THE OCTAVE

It has not always been common to have twelve notes per octave. Listed below are some deviating octave distributions.

<u>Tones per octave</u>	<u>Name</u>	<u>Intervallic distance</u>	
5	Gamelan slendro (Java)	approx. 240	cents
7	Pelog (West Indies)	approx. 171	cents
19	W. S. B. Woolhouse (1835) F. W. Opelt (1852)	approx. 63	cents
29	Cheve (1846)	approx. 41	cents
31	Christian Huygens published in 1695	approx. 38-1/2	cents
41	Jankó (1906)	approx. 29	cents
43	Sauveur (1707)	approx. 28	cents
50	Heufling (1700)	approx. 24	cents
53	Mercator (1620-1687) Bosanquet (1875)	approx. 22-1/2	cents

In 1555 Vicentino built an organ (Arci-organo) which had nineteen notes per octave. Each chromatic was doubled, plus keys between e - f and b - c. Earlier, in 1548, Zarlino built a two octave organ having a similar octave distribution.

In 1619 in his Syntagma musicum (Organographica), Praetorius described a harpsichord made in Prague in 1588. This harpsichord had 77 keys and utilized double chromatics: c-sharp and d-flat, d-sharp and e-flat, etc.

Mersenne and Kircher also described keyboard instruments which divided the octave into 17 to 27 notes. Inasmuch as these instruments were particularly complicated and difficult to play, they were not very popular.

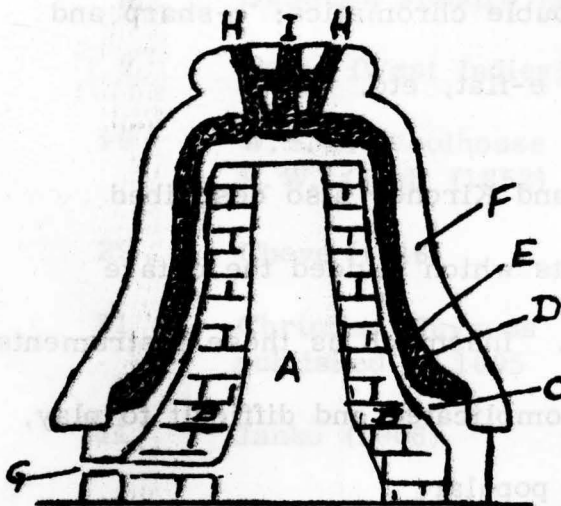
Since the early 1800's, equal temperament has been accepted in almost every country in the world and has triumphed over all other tonal systems, regardless of its intervallic impurity.

CHAPTER XXVIII

THE CASTING PROCESS

The parts of the mold which are used in bellfounding are:

- A. hollow core used for heating, hence drying the mold
- B. brick core
- C. coarse layer of loam
- D. thin smooth layer of loam
- E. false bell
- F. outer mold composed of loam and often called mantle or cope
- G. opening for heat to enter the mold for drying
- H. openings (taps) through which exhaust gases and air may pass during the pouring of the bronze
- I. opening through which the bronze is poured



(Loam is a combination of fine sand and approximately 40% clay. Chaff, peat or horse manure is added to give it the necessary texture so that it can be easily manipulated and thinly applied. Loam permits the unwanted gases, which could make the bell porous, to escape.)

The first step in casting a bell is paperwork. After size, proportions and curvature calculations are completed, a stencil¹ is made showing the exact profile of the desired bell. The amount of bronze necessary is also calculated.

A rough core of bricks is then constructed over which a coarse layer of loam is applied. After the loam is dried, a thinner layer of fine loam is applied until it is the exact thickness for the mold (inner surface of the bell profile). After this last layer is dry, a thin coating of graphite is applied. The false bell, having the same dimensions as the ensuing bronze bell, is now made of loam over the graphite. It is finished to the exact measurements of the desired bell and constitutes the base for the mold for the outer side of the bell

(outer surface of the bell profile). All inscriptions and adornments are placed on this false bell in wax, after which another layer of graphite is applied and the making of the mantle begins. First, fine textured loam is applied, followed by coarse loam strengthened with hemp. The false bell now rests between two molds, the core and mantle. Heating the molds causes them to dry and also melts the wax, leaving the inscriptions and adornments embedded in the mantle. Once dry, the mantle is carefully lifted from the core, the false bell is broken up and removed, and the mantle carefully and accurately replaced. The space once occupied by the false bell is now filled with molten bronze. After cooling, the mantle and core are removed from the bell. It is then cleaned and polished by a rotating steel brush until it shines. The bell can then be tuned.

The Benedictine monk, Theophilus, wrote about bellfounding during the Middle Ages in his De diversis artibus (chapter entitled "De campanis fundendis"). It seems most plausible that he lived

during the twelfth century in a monastery called Helmarhausen, although some sources have him living in the tenth century in Cologne. His manuscript is also entitled Diversarium artium schedula² and contains chapters on bellfounding, organ building, gold and silver smithery, etc.

In the casting process, Theophilus used a horizontal axis on which he shaped the bell. This cylindrical axis was made of dry oak and could be rotated by turning a handle affixed to an end. As the axis was rotated, layer upon layer of loam was applied, after each preceding layer was dried by building a small fire under it. After the desired thickness of the loam was achieved, it was chiseled to the exact shape of the inside profile of the desired bell, thus the core.

The false bell was made entirely of wax which was applied evenly over the surface of the core. Only the lower rim of the bell (sound-bow) was made somewhat thicker by applying additional layers of wax. By using a warmed chisel this wax false bell was made as symmetrical as possible.

Adornments and inscriptions were engraved in the wax and, once cast, embedded in the bell, not embossed as is common today.

After further layers of loam were applied to the false bell (with the exception of the upper shoulders and head of the bell), they formed the mantle and were allowed to dry. The axis was then carefully removed from its supports and, with much caution, tapped out of the mold. With any luck the mold, with its center of wax, remained intact.

Molds for the upper part of the bell, including the crown, were made and attached to the existing mold. Before they were joined, an iron eye was installed in the upper interior of the mold from which the clapper would suspend. Holes were made in the molds for the bronze to enter and the gases to escape.

Then the false bell was removed, which was done simply by heating the mold, causing the wax to melt.³ Heating the mold not only

removed the wax false bell but also tempered the molds to better withstand heat. After the mold was placed in a pit⁴ which was subsequently filled and firmly stamped, the casting process would begin.

The method of forming molds by using a horizontal axis continued through the sixteenth century. Even the large Van Wou bell in Erfurt, Germany, was made with this procedure. The method of forming bells with a vertical axis was used for some time for small bells and was later applied to the making of large bells in the seventeenth century.

It is easy to understand why these hand-shaped bells did not have a particularly beautiful tone. The bellfounders were only concerned with exterior tuning, being unaware that interior tuning was possible. When casting cymbala or tintinnabula, they tried only to cast bells sounding a diatonic scale.

The "Bellfounders Window", a stained glass window in the Munster Church in York, England, beautifully depicts the shaping of a bell by employing a horizontal axis.

The German bellfounder, Christoff Sesselschreiber, has left us an accurate description of this method used in 1524. He also wrote about the method employing a vertical axis and was quite versed with the use of the sjablone.¹ He illustrated the shaping of a bell by using a sjablone which was connected to the top of the vertical axis. As the sjablone was rotated around the axis, loam was applied to its dimensions. The lower part of the sjablone was stabilized by a makeshift rail.

In 1540, Vannoccio Biringuccio (Venice) also wrote a description of shaping a bell with a vertical axis. Besides writing much that had previously been written by Sesselschreiber, he also mentioned the possibility that the sjablone could be secured to the top of the vertical axis and the molds rotated. It was no longer necessary to have the false bell made exclusively of wax, but rather it could be made of loam with a thin coating of wax.

The largest bell cast by Theophilus that is

still in existence is the Lullus bell in Hersfeld, Germany. His bell from Aschara, in Thuringen, is now in the bell museum in Apolda, East Germany. All of his bells have the beehive shape.

Some examples of early bellfounding when the sjablone was not used can still be found in the Netherlands. A little bell dating from the twelfth century and having the shape of a "sugar-loaf" is in the Catharine Church of Buchten, municipality of Borm in Limburg. A bell dating from the twelfth or thirteenth century was found in Kortezwaag in Friesland and is now in the Rijksmuseum. A small bell cast in 1284 was in Schillard, Friesland, but is now at the Fries Museum. Another bell in the Rijksmuseum is dated 1285 and was found in Hekelingen, South Holland. Yet another old bell was cast in 1318 in Niftrik, Gelderland, and is now in the Bell Museum in Asten.

One of the oldest bells shaped with a sjablone in the Netherlands is still in the tower of the Catholic Church in Melick, Limburg. It was cast in 1337 and has a diameter of 95 cm. Similar

bells can still be found in Gemonde, municipality of Boxtel, North Brabant (1339); in Linne, Limburg (1349); 't Hof, municipality of Bergeijk, North Brabant (1367); Erp, North Brabant (1381); and in Megen, North Brabant (1399).

Although it is obvious that bells were being cast with the assistance of a sjablone as early as the fourteenth century, most bells cast during that century were shaped without sjablone. Examples of these may be found in Bolsward, City Hall (1320); Wirdum, Dutch Reformed Church (1338); Tiel, Dutch Reformed Church (1375); Sluis, City Hall (1400); Schoonhoven, Dutch Reformed Church (1416); and in Staphorst, Dutch Reformed Church (1417).

It is worth noting that the use of the sjablone was first popular in the southern parts of the Netherlands and later became fashionable in the northern parts. This is obvious by comparing the dates and places mentioned above.

The methods used in bellfounding today are

not much different from those already described.

The use of a vertical axis and rotating sjablone is common. However, some bellfoundries, including Eijsbouts, employ the method described by Biringuccio which uses the stationary sjablone and a rotating table.

Loam is most often replaced with a special blend of cement and sand. The casting pit is still used for large bells while an iron cope, being somewhat larger than the mantle, is used for small bells. The mantles for both large and small bells must be securely braced, for it is the reinforcements which keep the molds from breaking under the intense pressure generated during the casting process.

The core and the false bell are joined together by a light layer of talc, moist ashes or paper. After the false bell has been removed, both the core and the interior of the mantle are covered with a thin coating of graphite so that the bell will not bake to the molds.

Résumé of the casting process:

1. Make the sjablone to the exact proportions of the desired profile.
2. Construct the core by using bricks, loam or cement and sand. Ground cinder blocks are also effective when mixed with cement.
3. Shape the correct inner profile by using the sjablone.
4. Coat the core with talc, or the like.
5. Form the false bell of loam or cement and sand.
6. Apply a thin layer of wax to the false bell so that it correctly corresponds with the outer profile.
7. Inscriptions and adornments of wax are now placed on the false bell, which is an exact replica of the bell to be cast.
8. Cover the false bell with a fine layer of loam or sand. Build upon this with additional layers of loam or cement and sand.
9. Firmly press the mold into its casing and affix the necessary bracings.

10. Make the casting taps and other holes so that air and unwanted gases may escape through the top of the mold. From a casting basin at the top of the mold which will direct the molten bronze down the casting taps.
11. Heat the mold so that the wax layer and lettering will melt.
12. Remove the mantle very carefully.
13. Remove the false bell.
14. Cover the core and inner side of the mantle with a thin coat of graphite. (Earlier, soot and milk or egg whites were used.)
15. When both molds are dry, carefully replace the mantle over the core.
16. Tap the furnaces and pour the molten bronze into a casting bucket and then into the mold, keeping all ashes and brine out of the mold.
17. After the proper cooling time (one or two days according to the size of the bell), the mantle is carefully loosened from the bell and removed.

18. The core is removed and the bell is cleaned with a spinning wire brush.
19. After checking the tone, the bell is tuned.
20. Ring it.⁵

¹ Translator's note: Once the stencil for the profile has been drawn on paper, it is transferred onto a piece of wood which will be used for the actual measurements of the false bell. The wooden guide is called the sjablone, strickle board, or sweep.

² Translator's note: See Author's note 2, Chapter I.

³ Author's note: This method of bellfounding is often called the 'lost wax method'.

⁴ Author's note: Commonly called 'casting pit'.

⁵ Translator's note: Translator's addition.

Het Einde

APPENDIX I

Important Dissertations and Literature

Concerning Acoustics

- Aaron, Pietro. Libri Tres de Institutione Harmonica.
Bologna, 1516.
- Aristophanes. Tuning where every whole tone equals
identical major half tones. 320 B.C.
- Aristotle. Treatise on sound. 350 B.C.
- Boetius Anicius Manlius Severinus. Institutio Musica.
510 A.D.
- Bosanquet, Bernard. The Theory of the Division of the
Octave and the Treatment of the Musical System
Thus Obtained. 1874.
- Bouassé, H. Bases physiques de la musique. 1906.
- Cornu et Mercadier. Sur les intervalles musicaux
mélodiques. 1872.
Discovered by investigation that singers,
violinists and cellists used Pythagorean intervals
when performing solo, but not in harmony.
- Doppler, Christian Johann. Doppler effect: the
apparent difference of the frequency undulation
during movement between source and receiver,
i. e., swinging bell (bim-bam). Vienna, 1842.
- Dupont, W. Geschichte des musikalischen Temperatur.
1935.
- Ellis, A.J. History of Musical Pitch. London, 1880-81.
- * Ellis, A.J. Tonometrical Observations. London, 1889.
Used for comprehension of 'cents'.

Note: The asterisk (*) indicates works of particular importance.

van Eschbroek, Prof., and Montfoort, J. Qu'est-ce-que
jouer juste? 1946.

A treatise on a pipe organ with a small
range having chords tuned in different temperaments.

Euclid. Scales. 300 B. C.

Euler, Leonhard (Swiss). Tentamen Novae Theoriae.
Petropolis. 1739.

Fogliani, Lodovico. Musica Theoretica. Venice. 1529.

* Fokker, Dr. A. D. Rekenkundige bespiegeling der muziek.
Gorinchem, 1947.

(Mathematical Contemplation of Music) .

Frits, Barthold. Anseisung wie man Claviere, Clavecins
und Orgeln, nach einer mechanischen Art, in alle
zwolf Tonen rien stimmen konne. Leipzig, 1756.

* Galilei, Vincenzo. Dialogo della Musica Antica et della
Moderna. Florence, 1581.

Rebittal to Gioseffo Zarlino concerning
frequencies, consonance, and dissonance.

Galilei, Vincenzo. Discorso intorno all' Opere di Messer
Gioseffo Zarlino. Florence, 1589.

Glareanus, Henricus. Dodecachordon. Basel, 1547.

Greene. Violin Performance with Reference to Tempered,
Natural, and Pythagorean Intonation. 1937.

He discovered by electro-acoustical frequency
measurements that violinists use neither the
Pythagorean interval nor the natural tones. The
average for a third was 338 mo., thus somewhat
smaller than the Pythagorean.

Haba, Aloys. Neue Harmonielehre. 1922.

Haba, Aloys. Die Theorie der Vierteltönen. 1922.

A treatise concerning a piano with quarter
tones (Grotian-Steinweg).

Händel, George Frederic. In 1747 he suggested that the organ of the Foundling Hospital in London have the pipes changed from C-sharp, G-sharp, E-flat, and B-flat to other pipes giving the tones D-flat, A-flat D-sharp, and A-sharp respectively.

von Helmholtz, Hermann. Die Lehre von den Tonempfindungen. Braunschweig, 1862.

Harmonium with two tones per key assisted by stop-couplers.

* Huygens, Christian. vus cyclus harmonicus. 1691.
31 tones per octave.

von Jankó, Paul. Über mehr als zwölfstufigen Temperaturen. 1901.
41 tone systems per octave.

Jeans. Science and Music. 1937.

Kallenbach-Greller. Die historischen Grundlagen der Vierteltönen.

Kircher, Althanasius. Musurgia Universalis sive Ars Magna Consoni et Dissoni. Rome, 1650.

Kircher, Athanasius. Phonurgia Nova. Campinado, 1673.

* Kok, Ir. W. Harmonische orgels. Delft, 1955.
(Harmonic Organs)

An outstanding investigation into the different temperaments using the electric organ with adjustable tuning at the Technical University of Delft.

Loman. De logische grondslagen der muziek. 1929.
(The Logical Fundamentals of Music)

An investigation of two pianos, one with Pythagorean intervals and the other with harmonic intervals. Professional musicians usually choose the Pythagorean intervals.

Loman. De muzikale betekenis van het enharmonische interval. 1933.

The musical significance of the nonharmonic interval.

Marpurg, Fr. W. Versuch über die Musicalische Temperatur. Breslau, 1776.

* Mersenne, Marin. L'Harmonie Universelle. Paris, 1636.

Speed of sound and calculating vibrations.

Miller, D. C. Anecdotal History of the Science of Sound. New York, 1935.

Miller, D. C. The Science of Musical Sound. New York, 1917.

von Möllendorf. Musik mit Vierteltönen. 1917.
Bi-chromatic harmonization.

Norden, N. Lindsay. A New Theory of Untempered Music. 1936.

Paumann, Conrad. Fundamentum Organisandi. 1452.

van den Pol, B., and van den Mark, J. Frequency Demultiplication. 1927.

Poole. Über rein gestimmte Orgeln. 1850.

A temperament with all fifths 0.2 mo. too large, thirds perfect and limited choice of key signatures. In 1867 an organ was tuned with 78 tones per octave having perfect thirds, perfect fifths, and harmonic sevenths.

Praetorius, Michael. Syntagma Musicum (Organographica) 1619.

Ptolemy, Claudius. Relation of Tones and Colors. 130 A. D.

Pythagoras. Tuning in the Pythagorean Temperament. 550 B. C.

Rameau, J. Ph. Traité de l'Harmonie. Paris, 1722.

Riemann, H. Wissenschaftliche Grundlâge der Music-Theorie. 1891.

Sauveur, J. Differentiation of the overtones and the fundamental: a string vibrates as a whole and in segments at the same time giving rise to overtones. 1701.

- Scheibler. "Über mathematische Stimmung. 1835.
- * Schlick, Arnold. Spiegel der Orgelmacher und Organisten. 1511.
- Schouten, Dr. J. F. The Perception of Subjective Tones. 1938.
- Schouten, Dr. J. F. The Residue, a New Component in Subjective Hearing. 1940.
- Schouten, Dr. J. F. De toonhoogtegewaarwording. 1940.
(Delineation of Pitch)
- Small. An Objective Analysis of Artistic Violin Performance. 1937.
- Stevin, Simon. Van de Spiegeling der singkonst. Bruges. 1620.
Calculation of the equal temperament to the accuracy of four decimals.
- Tanaka. Studien im Gebiete der reinen Stimmung. 1890.
- Tartini, Giuseppe. De 'Principi dell' Armonica Musicale. Padua, 1767.
- * Tartini, Guiseppo. Trattato di Musica. Padua, 1754.
Tone differentiation.
- Thompson. Principles and Practice of Just Intonation, Illustrated on the Enharmonic Organ. 1863.
- Vicentino. L'Antica musica ridotta alla moderna prattica. Descrizione dell' arci-organo. 1555.
Description of an organ with double black keys and keys between e-f and b-c.
- Werckmeister, Andreas. Erweiterte und verbesserte Orgelprobe. 1692.
Application of equal temperament.
- Woolhouse, W. S. B. Essay on Musical Intervals, Harmonies and the Temperament of the Musical Scale. 1835.

Zarlino, Gioseffo. Dimostrazione Harmoniche. Venice, 1571.

* Zarlino, Gioseffo. Le Institutione Harmoniche. Venice, 1558.

Treatise on Tuning.

Zarlino, Gioseffo. Supplimenti Musicali. Venice, 1588.

APPENDIX II

Literature about Bells, Carillons and the Tuning of Bells

Arnhem Municipal Museum, De Grote Kerk van Arnhem.
W.H. Tiemens, 1964.

(The Large Church of Arnhem)

This work contains much valuable information
about the carillon and swinging bells of Arnhem.

The swinging bells of Arnhem are:

G	1961	Petit & Fritsen	206 cm.	5320 kg.
B-flat	1477	Van Wou	175 cm.	3175 kg.
C ¹	1961	Petit & Fritsen	155 cm.	2247 kg.
E-flat ¹	1650	Hemony	128 cm.	1340 kg.
G ¹	1650	Hemony	103 cm.	686 kg.
A-flat ¹	1650	Hemony	97 cm.	576 kg.
(perhaps g-sharp retuned)				
B-flat ¹	1650	Hemony	86 cm.	393 kg.

(Both the G and the B-flat are used in the carillon.)

* Arts, Brother Getulius. The Sound of Bells. 1938.

The author names the 'secondary strike-tone'.

* van Assumburg, H. Waar de klepel hangt. Nijkerk (no date)
(Where the Clapper Hangs.)

This book contains a good description
of the founding process.

Becket, E. (6th ed.). Clocks, Watches, and Bells.
London, 1874.

Berthelé, Jcs. Ephemeris Campanographica. Montpellier,
1910.

Biehle, J. Die Analyse des Glockenklanges. Leipzig, 1919.

(The Analysis of the Bell Sound.)

Bigelow, Arthur L. Carillon. Princeton, 1948.

* Bigelow, A.L. The Acoustically Balanced Carillon. Princeton, 1961.

This book includes chapters on the influence of the profile and weight, etc., on the timbre of a bell, and also research into clapper effects.

* Bijtelaar. De zingende torens van Amsterdam. Amsterdam, 1947.

(The Singing Towers of Amsterdam.)

* Biringuccio, Vannoccio. De la pirotechnica. Venice, 1540.

* van Blankenburg, Quirinus. De Noodzakelijkheid van de cis en de dis in de bassen der klokken (Gouda), 1676.

(The Necessity of C-sharp and D-sharp in the Lowest Octave of a Carillon.)

Blessing, P.J. Harmonie der Glocken. Düsseldorf, 1906.
(The Harmony of Bells.)

Blessing, P.J. Über den Klang der Kirchenglocken. 1911.

Boecheler, H. Beiträge zur Glockenkunde. Aken, 1882.

Bouassé, H. Cloches et carillons. Paris, 1927.
(Bells and Carillons)

Bouassé, H. Verges et Plaques Cloches et Carillons. Paris, 1929.

Buys, M.A. Brandts. Klokkenspelen in Nederland.
's Hertogenbosch, 1922.
(Carillons in the Netherlands.)

Buys, M.A. Brandts. Nederlandse klokkengieters.
's Hertogenbosch, 1925.
(Dutch Bellfounders.)

Coleman, S.N. Bells. New York, 1928.

van Doorslaer, G. Oorsprong en ontwikkeling der
beiaardkunst. 1922.
(Origin and Development of the Carillon Art.)

Dorgelo, A. De klokkengieters Van Trier en hun werk.
1961.
(The Bellfounders Van Trier and Their Work.)

Ellerhorst, W. Hanbuch der Glockenkunde. Weingarten,
1957.
(Campanological Handbook)

van der Elst, Dr. W. Inventarisatie van klokken in Nederland.
1940.
(Inventory of the Bells in the Netherlands.)

* van der Elst, Dr. W. De Klokken van de Domtoren te
Utrecht. Amsterdam, 1929.
(The Bells of the Dom Tower of Utrecht)
This book is particularly interesting,
having much concerning the Hemony brothers.

* Fehrmann, Dr. C. N. De Kamper klokkengieters, hun naaste
verwanten en leerlingen. Kamper, 1967.
(The Kamper Bellfounders, Their Next of Kin
and Pupils.)
This is an outstanding summary of the
development of the European art of bellfounding.
Much emphasis is given to Van Wou, Wegewaert, etc.

* Fischer, J. P. A. Verhandeling van de klokken en het
klokkenspel. Utrecht, 1738.
(A treatise on bells and carillons.)

Goguet, Jaqueline. Le carillon des origines à nos jours.
Paris, 1958.
(The Carillon from its beginnings to our time.)

Griesbacher, P. Glockenmusik. Regensburg, 1927.
(Bell Music.)
Treatise on swinging bells.

Griesbacher, P. Glockenstimmung. Regensburg, 1927.
(Tuning of Bells.)
Treatise on swinging bells and overtones.

Hahn, J. G. Kampanologie. Erfurt, 1802.

Harrison, J. An Introduction to a Treatise on the Proportions of Bells. Hull, 1831.

Harzer, F. Die Glockengiesserei. Weimar, 1854.
(The Bell Foundry.)

Heinrich, O. Glockenkunde. Leipzig, 1858.
(Campanology.)

Hekker, R. C. Klokken van Amsterdamse gieters.
(Bells from Amsterdam Founders.)

* Hemony, Pieter. De ondienstigheid van de cis en de dis in de bassen der klokken. Delft, 1678.
(The Uselessness of C-sharp and D-sharp in the Lowest Octave of a Carillon.)

's Hertogenbosch. Handelingen van het tweede congres Beiaardkunst. 1925.
(Report of the Second Carillon Congress.)

* van Heuven, Ir. E. W. Acoustical Measurements on Church Bells and Carillons.

This treatise has been important for the development of the art of bellfounding in the Netherlands after the Second World War.

Holmbäch, L. M. Klocker och klockringning. Stockholm, 1951.
(Bells and Bell Ringing.)

Hullebroeck, E. Beiaarden. Brussels, 1924.
(Carillons)

* Jones, A. T. The Strike-Note of Bells. New Haven, 1930.
The strike-note is identified as related to the octave below the fifth partial.

Jones, A. T. The Vibration of Bells. Minneapolis, 1928.

Jones, A. T., and Aldermann, G. W. Further Studies of the Strike-Note of Bells. Menaska, 1931.

- Kalm, Dr. J. Carillons zijn monumenten. 1953.
(Carillons are Monuments.)
- Launay, J. B. Der vollkommene Glockengiesser.
Quedlinburg, 1834.
(The Complete Bellfounder.)
- Lehr, André. Historische en musikale aspekten van Hemony beiaarden. Asten, 1960.
(Historical and Musical Aspects of the Hemony Carillons.)
- * Lehr, André. De klokkengieters Francois and Pieter Hemony. Asten, 1959.
(The Bellfounders Francois and Pieter Hemony.)
- Llewellyn, J. Bells and Bell Foundry. Bristol, 1879.
- Loebmann, H. Das Glocken-ideal. Berlin, 1928.
(The Ideal Bells.)
- Loebmann, H. Über Glockentöne. Leipzig, 1915.
- * Loosjes, A. De torenmuziek in de Nederlanden.
Amsterdam, 1916.
(Tower Music in the Netherlands.)
- Lukis, W. C. An Account of Church Bells. London, 1857.
- Maguis, H. De Tintinnabulis. Amsterdam, 1664.
- Mahrenholz, Chr. Glockenkunde. Kassel, Basel, 1948.
(Campanology)
Including chapters on history, profile,
strike, and materials.
- Mechlin. Handelingen van het eerst congres voor Beiaardkunst. 1922.
(Reports of the First Carillon Congress.)
- Meyer, E., and Klaes, J. Über den Schlagton von Glocken.
Berlin, 1933.
Relation of strike-tone with 5th and 8th
partials - 14 and 15 - thus an octave plus a
12th partial for the fundamental tone C: c^2 and g^2 .

Nederlandse Klokkenspel-Vereniging, Historische Commissie
Klokken en klokkengieters. N. K. V. (Dutch Carillon
Guild), 1963.

This work contains information about the
art of bellfounding in the Middle Ages.

Nichols, J. R. Bells Thro' the Ages. London, 1928.

- * van Nunes, A. Experimenteel onderzoek van klokken
van Francois Hemony. Amsterdam, 1909.

(Experimental Research into the Bells
of Francois Hemony.)

Established the secondary strike note and
explained the vibration of bells: nodal-circles, etc.

Pacichellius, J. B. De Tintinnabulo. Naples, 1693.

- * Pfnor. Zur Akustiek der Glocken. Darmstadt, 1848.

(The Acoustics of Bells.)

Treatise on the tuning of the fundamental.
(See sketch by Simpson placing the tuning
function of the hum-tone at c-g on the inner
side and at d-f on the outer side.)

- * Price, Percival. Campanology. Ann Arbor, 1945-46.

An outstanding document about the
condition of bells in Europe directly after
the Second World War.

- * Price, Percival. The Carillon. Oxford, 1933.

Raleigh, Lord. On the Tones of Bells. Phil. Mag., 1890.

- * Raleigh, Lord. The Theory of Sound (2 volumes),
1st printing 1877 and 2nd printing 1894.

The pitch of the strike-note lies one octave
below the 5th overtone.

- * Rice, William Gorham. Beiaarden in de Nederlanden.
Amsterdam, 1927.

(Carillons in the Netherlands.)

- * Rice, William Gorham. Carillon Music and Singing
Towers of the Old World and the New. New York,
1930.

* Rice, William Gorham. Carillons of Belgium and Holland. 1914-15.

* Rice, William Gorham. Carillon Towers of the Old World and the New. 1925.

Rolli, H. Kirchengeläute. Ravensburg (no date).

This work includes chapters on bell hanging, yokes for swinging bells and combinations of swinging bells.

* Rottiers, Jef. Beiaarden in Belgie. Mechlin, 1952.
(Carillons in Belgium.)

Sartori, P. Das Buch von Deutschen Glocken. Leipzig, 1932.

Schafhaeutl, K. E. Untersuchung über die Töne der Glocken. Munich, 1868.

* Schouten, Dr. J. F. The Residue, a New Component in Subjective Sound Analysis.

The secondary strike-note is the residue of the partials between I-6 (double nominal) and I-9 (triple nominal) wherever these important harmonics lie. This is true only for bells heavier than approximately 750 kg.

* Schouten, Prof. Dr. J. F., and 't Hart, J. (uncle of Leen). De slagtonen van klokken. Eindhoven, 1965.
(The Strike-note of Bells.)

This book distinguishes between:

- a. the strike sound; having a very metallic character and being atonal. It does not have much resonance.
- b. the strike-note is the fixed melody note of the bell and decays relatively quickly.
- c. the fundamental; an over-tone of the bell, is the melodic tone, continues considerably longer than the strike-note with a pure timbre.

* Sesselschreiber, Christoph. The forming of a bell on a horizontal axis as well as on a vertical axis, 1524.

* Simpson, A. C. On Bell Tones. Pall Mall Mag., 1895.

Simpson, A. C. Why Bells Sound Out of Tune. How to Cure Them. Pall Mall Mag., 1896.

Spruyt, J. Klokken in Nederland en elders. Amsterdam, 1740.

(Bells in the Netherlands and Elsewhere.)

Spruyt, J. Methode om het klokkenspel to accorderen (manuscript). Amsterdam, 1740.

(Techniques for tuning a carillon.)

Starmer, W. Wooding. Bells and Bell-Tones. London, 1902.

Starmer, W. Wooding. Carillons. London, 1915.

Sturm, Sigrid. Deutsche Glockenatlas. (Beieren und Schwaben). Munich, Berlin, 1967.

* Theophilus. Forming a bell with a horizontal axis using the lost wax method. Cologne, 10th or 12th century.

Thybaud, A. l'Harmonisation des cloches d'églises. Lapriz, 1898.

* Timmermans, Ferd. Luidklokken en beiaarden in Nederland. Amsterdam, 1944 and 1950.

(Swinging Bells and Carillons in the Netherlands.)

This is a scholarly book being a particularly fine popular history.

Tyzzer, F. G. Characteristics of Bell Vibration. Philadelphia, 1930.

van der Ven, D. J. De torens zingen. Amsterdam, 1910.
(The Towers Sing.)

* Verheyden, Pr. Beiaarden in Amerika. Antwerp, 1928.
(Carillons in America.)

- * Verheyden, Pr. Beiaarden in Frankrijk. Antwerp, 1926.
(Carillons in France.)

Vernet, Marc. Cloches et musique. Neuchâtel, 1963.

Deals with the founding process, the combinations of a small number of bells, and the problems of bringing out the melody. In Switzerland an early predecessor of the carillon is still played (also in Italy); that is, ropes are connected to the clappers.

- * van Waesbergen, J. Smits. Klokken en klokkengieters in de Middeleeuwen. Tilburg, 1937.
(Bells and Bellfounders of the Middle Ages.)

Walter, K. Glockenkunde. Regensburg and Rome, 1913.
(Campanology.)

Treatise including founding process, hanging of swinging bells, inscriptions, and combinations of swinging bells. A conclusive list of bellfounders and survey of important bells.

Walters, H. B. Church Bells of England. London, 1912.

Wijborn, A. De San Salvator. Aarle-Rixtel, 1960.
A sketch of the Hemony's environment.

- * Ziegler, Günther. Eherne Zungen. Berlin, 1966.
(Tongues of Brass)

Ehern = metal, iron, bronze (also = hard)
Zungen=tongue. This contains some history and is a good survey of the founding process.

APPENDIX III

Suggested Literature

van Assumburg, H., and Callenbach, C. F. Waar de
klepel hangt. Nijkerk.
(Where the Clapper Hangs.)

Bigelow, A. L. The Acoustically Balanced Carillon.
Princeton University, 1961.

Fokker, Prof. Dr. A. D. Rekenkundige bespiegeling
der muziek. Noorduy'n's Wetenschappelijke
Reeks, Gorinchem, 1945.
(Mathematical Contemplation of Music.)

van Heuven, E. W., and van Cleef, Gebr. Acoustical
Measurements on Church Bells and Carillons.
The Hague, 1949.

de Jong, Rinus. Klokkespullen yn Fryslan. Miedema
& Co., Ljouwert, 1965.

Kok, Ir. W. Harmonische orgels. Delft.
(Harmonic Organs.)

Lehr, André. De klokkengieters Francois en Pieter
Hemony. B. Eijsbouts C. V., Asten, 1959.
(The Bellfounders Francois and Pieter
Hemony.)

Lehr, André. Van Paardebel tot Speelklok. Europese
Bibliotheek, Zaltbommel, 1971.
(From Horsebell to Carillon.)

Miller, D. C. History of the Science of Sound. The
Macmillan Co., New York 1935.

Nederlandse Klokken spel-Vereniging, Historische Commissie.
Klokken en klokkengieters. Secr. N. K. V., 1963.
(Bells and Bellfounders.)

Pels, Ir. B.F.A.; Pels, Fa. B. and Son. Het orgel met
diezenstemming in Teylers museum te Haarlem.
Aklmaar, Christian Huygens tuning with 31
identical intervals per octave.

Stichting, Ratiobouw. Enige wetenschappelijke problemen
bij de bouw van kerken. Stichting "Bouw,"
The Hague, 1948.

(Ratiobouw Foundation presently in the
Bouwcentrum in Rotterdam.)

(Some Scientific Problems Concerning the
Building of Churches.)

Timmermans, Ferd., and de Lange, Allert. Luidklokken
en beiaard in de Nederlands. Amsterdam, 1950.
(Swinging Bells and Carillons in the Netherlands.)

van Waesberghe, J. Smits, and Bergmans, W. Klokken en
klokkengieters in de Middeleeuwen. Tilburg, 1937.
(Bells and Bellfounders in the Middle Ages.)

Westcott, Wendell. Bells and Their Music. Putnam, 1970.

Wijborn, A. De San Salvator. Petit & Fritsen,
Aarle-Rixtel, 1960.

Ziegler, G. Eherne Zungen. Evangelische Verlagsanstalt,
Berlin, 1960.
(Tongues of Brass.)

AND NOW FOR FUN:

Sayers, Dorothy L. The Nine Tailors. New English Library,
1934. (New edition, 1969.)