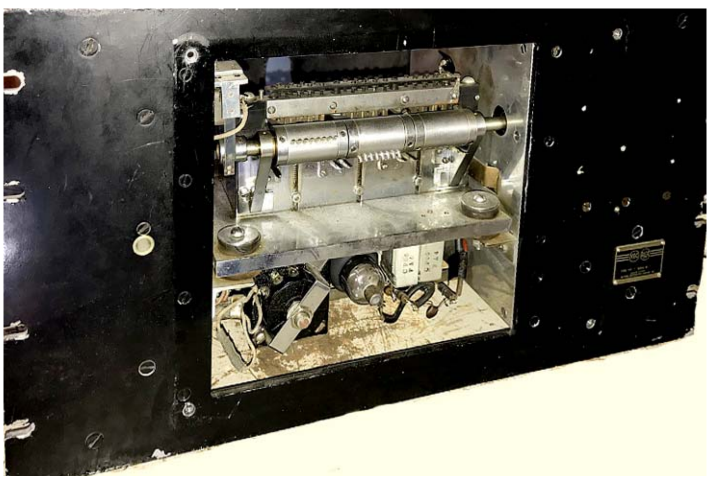
The NBC Chime Machine at CHRS

By John Staples,W6BM & John Stuart, KM6QX

Three-tone chimes custom made for NBC by J. C. Deagan, Inc.
Source RadioRemembered.org

As early as 1922, musical dinner chimes were used to identify radio station WSB in Atlanta, GA.(1) The soft-toned melodic dinner chimes, then in common use by cruise ships, railroads, theaters, and concert halls, were thought to add a touch-of-class to the station's radio broadcasts. A number of other radio stations followed suit. In 1926 the National Broadcasting Company (NBC) network was formed by using AT&T's telephone lines to distribute radio programming nation-wide. Six NBC switching centers were located in New York, Washington, Cleveland, Chicago, San Francisco, and Hollywood.(2) At the conclusion of each program (typically every 15 minutes), the dinner chime melodies were used as a switching cue for AT&T engineers to reconfigure their wireline networks to feed the next scheduled programs to the proper affiliate radio stations.

Various NBC dinner chime melodies were soon standardized to the familiar three notes *G-E-C* that everyone now associates with "NBC". By the mid 1930's, the hand struck chimes were replaced with custom built, motor driven, three-note 'music boxes' known as the NBC Rangertone Chimes Machine.(3)



Front view of the chime machine with rack mount ears, cover plate, and serial number badge. Front panel has been removed showing the rotating drum with pluckers, heavy vibration isolation plate, and amplifier components below.

CHRS Acquisition

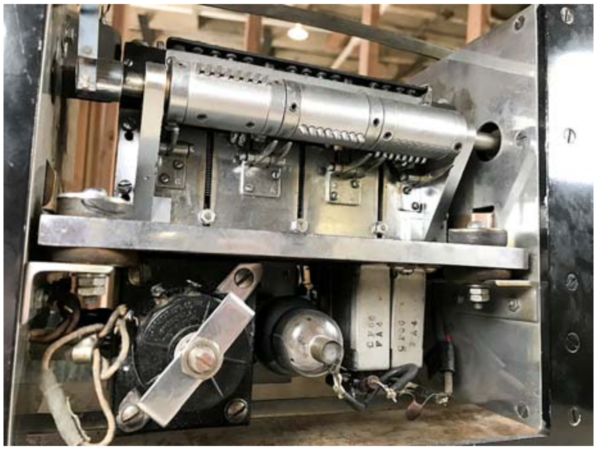
Last year, the California Historical Radio Society acquired *Serial No. 2* of these rare electro-mechanical music boxes. In 1932, this was one of two Rangertone chime machines originally installed in NBC's San Francisco Network Studios, which was located at 111 Sutter Street at the corner of Sutter and Montgomery Streets.

In 1942 it was probably moved to the (then) new NBC Radio City, an ultra-modern four-story studio complex at Taylor and O'Farrell Streets.(4) When it was removed from service, the chime machine became part of the Walt Palmer collection, and was then acquired by former NBC Engineer Bill Newbrough. In 1999, it was featured in The Radio Historian website, by John Schneider.(5) Then in 2018, Bill Newbrough donated NBC Chimes Machine Serial No. 2 to the CHRS.

This CHRS Journal article describes *Serial No. 2* in detail, and provides references to sources of information about these extremely rare artifacts of early radio network broadcasting. For more historical information about the use of chimes in radio broadcasting, see the referenced websites listed at the end of this article.

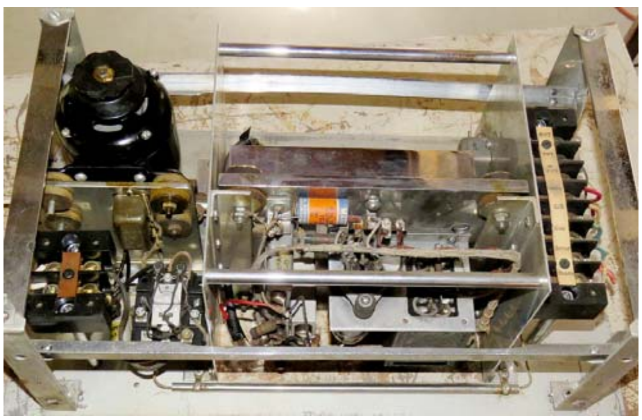
Mechanical Design

The NBC chime machine weighs a hefty 52 pounds and is built on the back side of a standard 10-1/2" x 19" aluminum rack panel. A 9" x 12" removable plate is provided in the panel for maintenance access. (see photo above). The back side has a removable 16.5" x 10" x 8" deep steel case which houses and electrically shields the mechanical systems, capacitive reed sensors, and vacuum tube amplifier.



A close-up better showing rotating drum with pluckers, heavy vibration isolation plate, and 6C6 amplifier components.

View of the capacitive pickup fingers and three vibrating reed combs. Note several reeds have been broken off.



View of the underside 6C6 amplifier circuitry, motor, and power supply.

The Telechron clock controller that accompanied the chime machine.

A 115 VAC Bodine Electric Company speed reducer motor is used to rotate a 1" diameter x 5.5" long drum at 17 RPM (3.5 seconds per revolution). The drum has three sets of fingers that pluck the three sets of reeds, as the drum rotates through one revolution. The motor and worm drive gearbox are mounted with vibration isolating rubber biscuits. The vibrating reeds, capacitive pickups, and rotating drum assembly are mounted on a very heavy steel plate which is also vibration isolated with rubber biscuits. Even the vacuum tube socket is vibration isolated. This vibration isolation prevents motor vibrations, relay clicking, and other rack/room noises from being picked up by the very sensitive capacitive reed sensors and vacuum tube amplifier.

The original design had a Bodine motor with a slower 10 RPM gear reduction.   They were later replaced in the field with 17 RPM motors to reduce air-time of the three tone chime, from 5.8 seconds to 3.5 seconds.

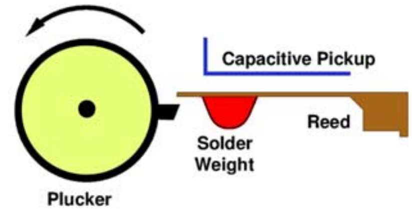
The Telechron clock (photo above) would have been part of several "Announcer's Delight" lectern control cabinets in NBC's studios. An announcer could press one of the buttons to trigger the chime machine prior to making his announcement. The switches are for both studio and "NEMO" broadcast lines. "NEMO" was a term used in early radio to indicate a remote broadcast; It comes from a telephone term "Not Emanating Main Office."[5]

How are the tones produced?

The early chime announcements were produced by the announcer on a hand-held xylophone. This led to many errors in timing and hitting the right notes.

So, instead, the chime sounds were produced electronically. Richard Ranger, a manufacturer of electronic organs already had a background in electronic musical instruments. At the request of NBC, he produced a machine to generate the chime signals.

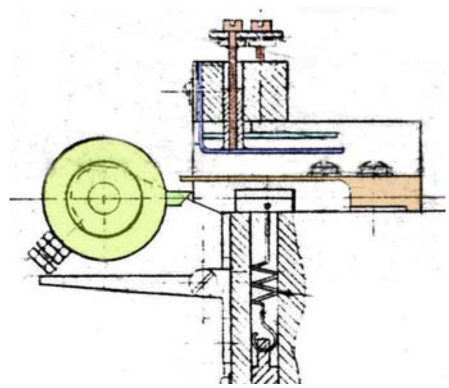
Instead of a xylophone arrangement, he elected to invent a device similar to a music box. A music box plucks tuned reeds which resonate using a soundboard to acoustically amplify the sound. Instead of a soundboard, Ranger used an electronic pick-off similar to that used in capacitor microphones. The machine emits very little acoustic noise as it plays: the output is an electrical signal.



As plucker (yellow) rotates, it strikes the reed (orange) producing a tone which is sensed by the capacitive pickup (blue).

Condenser microphones operate by placing a diaphragm, vibrated by pressure waves in the air near a charged plate forming a capacitor with a charge across the electrodes. When the diaphragm vibrates, the capacitance between the electrodes varies, inducing an alternating voltage between the electrodes. This voltage is amplified and that is the signal from the microphone.

The chime machine uses the same capacitance principle to generate the electrical signal.

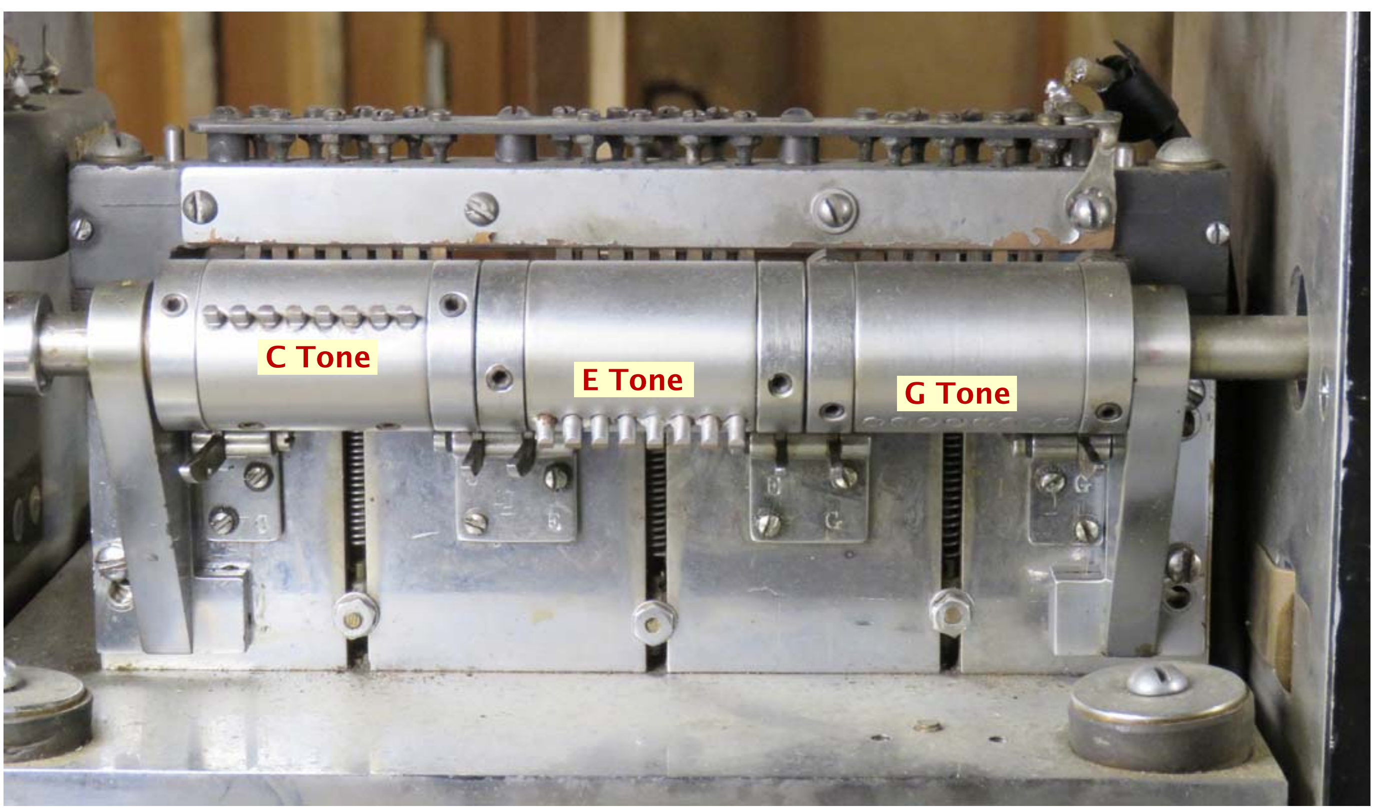

Manufacturer's drawing of a the mechanism.

The chime machine is fitted with a series of reed blocks for the three tones produced: G, E and C. A rotating drum with "pluckers" passes by the reeds, strumming them and setting them in motion.

Each tone consists of several individual notes than blend together. Three reed blocks each have up to eight individual reeds, each tuned to a separate note of the musical scale.

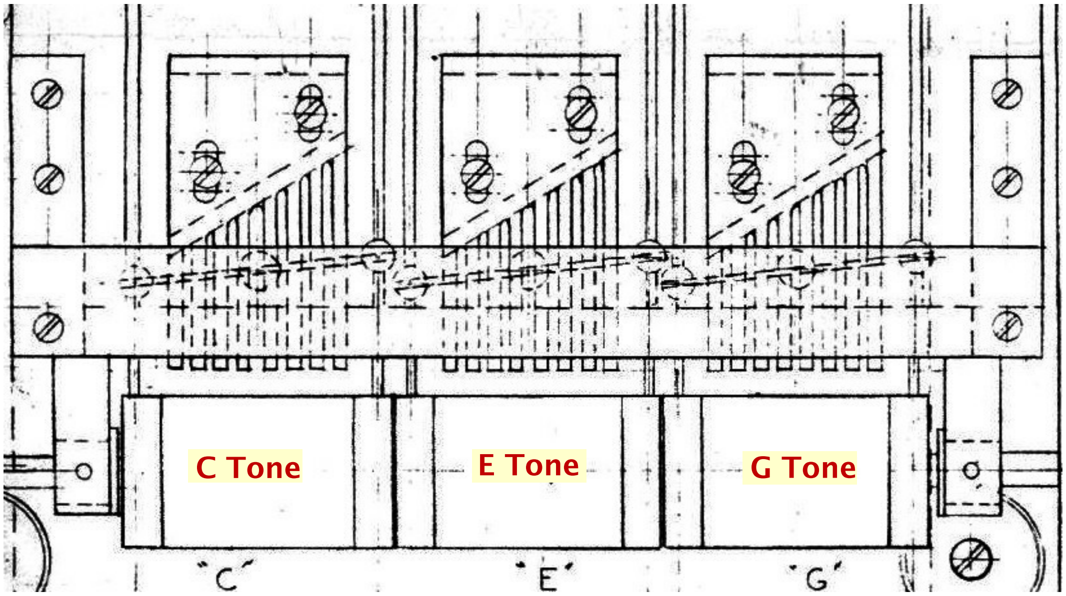
In addition to the pluckers, a set of dampers is applied to the reeds after a short time to quiet them so the three tones do not overlap each other. A large projection on the rotating drum engages a lever that lifts pads resting on the reeds, allowing the reeds to ring. A return spring below the pads returns the damping pads to the reeds, cutting off the vibration.

The three sets of reed plates are assembled in a row, with the G, E and C tones from right to left. A drive motor off to the right rotates the cylinder at the bottom which contains the "pluckers."



3-tone chime assembly.

The reeds are arranged behind the rotating drum that contains the pluckers.



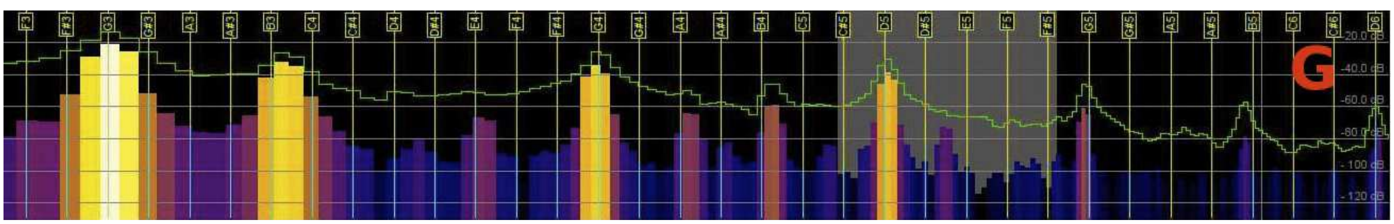
Manufacturer drawing of the 3 reed blocks.

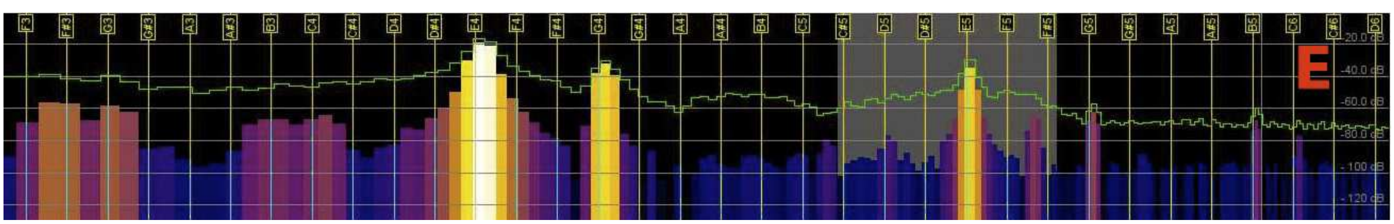
The first note, the "G", is produced by the reeds on the right, progressing to the "E" and the "C" note as the drum rotates. Note that there are eight pluckers, one each for the eight reeds for each note.

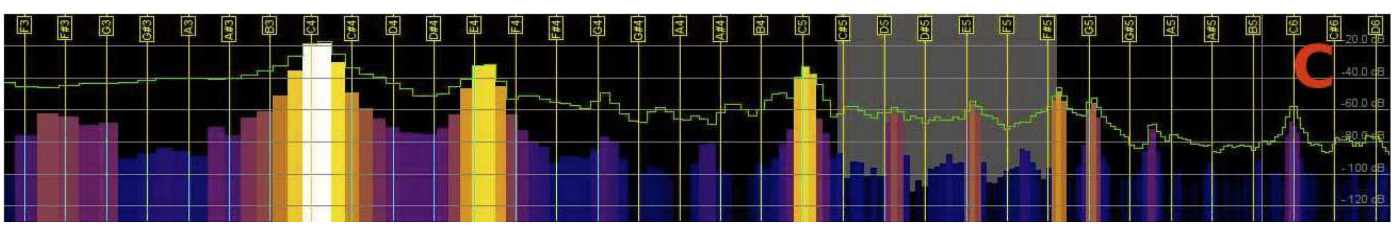
What are the tones that are produced by the reeds?

The electrical signal from the chime machine is recorded and analyzed to identify the individual frequencies produced for each of the G, E and C notes. The audio analysis tool SpectrumLab supplies the frequency plots.

The spectrum of each note, starting with G is shown here. The musical name of each note is shown.







The amplitude of the note is indicated by the brightness and the height of each line in the spectrum. Only the most significant notes are selected, as the others are too week to be heard, and may be a results of distortion products in the electronics.

The most intense frequencies contained in each note, along with the name of the note, derived from the spectral analysis are listed here.

G Chord	
Tone	**Frequency (Hz)**
G3	196.0
B3	246.94
G4	392.0
D5	587.33

E Chord	
Tone	**Frequency (Hz)**
E4	329.63
G4	392.6
E5	659.26

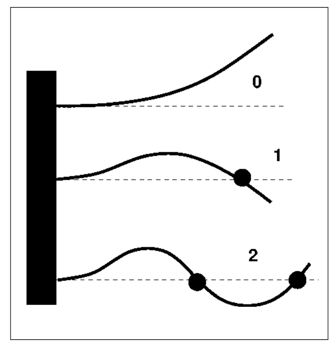
C Chord	
Tone	**Frequency (Hz)**
C4	261.63
E4	329.63
C5	523.33
F#5	739.99
G5	783.99

The frequencies chosen are closest to the musical notes in the scale: they may be slightly different, as the frequency resolution of the analyzer itself contributes an uncertainty. See the sidebar for an explanation of the equal-tempered musical scale and the names of the notes.

Tuning the Reeds

These reeds, if plucked without any additional weight attached, would resonate at a higher frequency than desired. Each reed forms a beam, or a cantilever, fixed at one end and free at the other. A plucked beam oscillates in several modes.

The modes are labeled by the number of zero crossings of the axis: 0, 1, 2 … The frequencies of the N = 1 and 2 modes are 6.3 and 17.6 times the fundamental N = 0 mode for an unweighted reed.



Modes of oscillation of a reed.

Using the dimensions of the reeds, the natural resonant frequency of each reed is with uniform cross section is calculated. The reeds appear to be made of steel. The frequency is given by

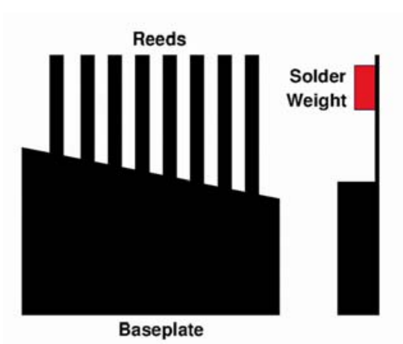
$$f\,(Hz) = \frac{1}{2\pi}\,\alpha_i^2\sqrt{\frac{E\,I}{\rho\,L^4}}$$

where ρ = 7850 kg/m^3, the density of steel, the Young's modulus E = 2.1x10^{11} kg/m-sec^2 , the "elasticity" of steel, $I = w\,h^3/12$ is the moment of inertial for a cantilever, fixed at on end and free at the other, where L w and h are the length, width and height of the reed. Alpha is a value related to the mode number, and is 1.875 for the fundamental mode.

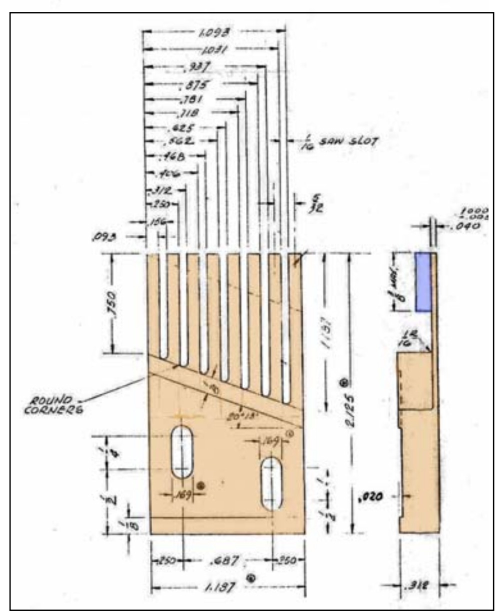
It turns out that the resonant frequency of a reed of uniform cross section is independent of the width of the reed, goes as the reed thickness to the 3/2 power, and goes inversely as the square of the length.

From the dimensions of the reeds shown in its drawing, the resonant frequencies in Hertz of the lowest mode, from the shortest to the longest are:

Reed	Resonant Freq. (Hz)
L1	2340.1
L2	1987.3
L3	1708.6
L4	1484.7
L5	1302.1
L6	1151.2
L7	1025.1
L8	918.7



Reeds have increasing length.


Manufacturer drawing of a reed block.

These frequencies are all higher than the ones actually measured. To tune the reeds to the desired frequencies, each has a solder weight attached near the open end to weigh it down and reduce the resonant frequency.

The calculation of the frequency with the added solder weight is complicated, as it depends on the detailed distribution of the added weight to the reed. It appears that solder was added to each read until the desired frequency was achieved.

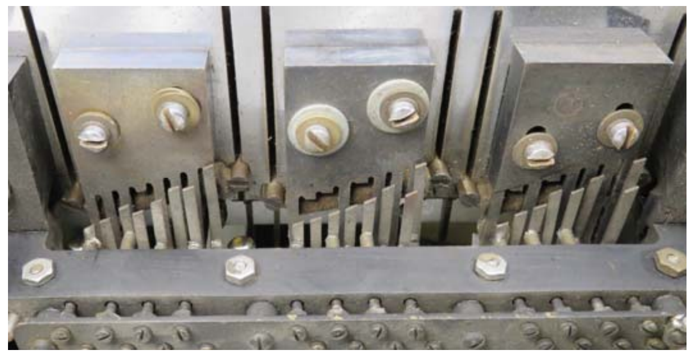
Here is a detail of the "G" reeds seen from underneath, with the "E" reeds to the left. Large blocks of solder are seen attached to the reeds, which are hidden behind the drum. It appears that some solder flux remains on some of the reeds.

Solder was added to a reed to tune it to the desired frequency.

Shaping the amplitude of the notes

The amplitude of the electrical signal from each reed depends on the distance from the capacitive pickoff electrode. The relative amplitudes seem to have been established to give the fundamental frequency the largest amplitude, with the other tones higher in frequency at lesser amplitude.

Each reed has a mating extension reed from the pick-off electrode bar, with each pick-off reed position determined by a set screw that positions the pick-off reed distance to the tone reed. The closer the pick-off to the tone reed, the higher the amplitude signal from that reed.



Pick-off reeds shown above the tone reeds.

The pick-off reeds are shown above the tone reeds. The screws that adjust the distance of the pick-off to the tone reed are in the pick-off support bar at the bottom.

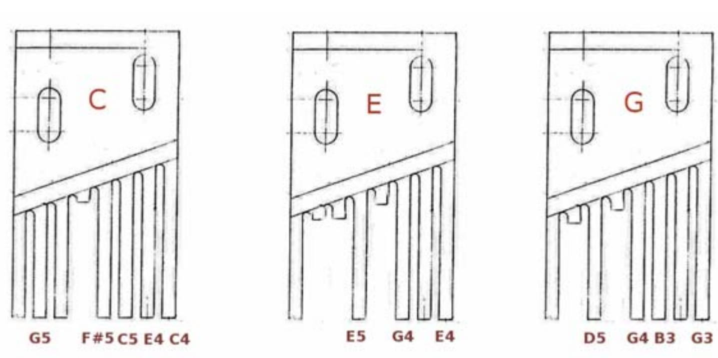
The fundamental note for each reed plate is on the right side, and the pick-off for that reed is seen in the picture to be close to the reed itself. Other capacitive pick-offs are seen to be farther away. The pickoffs that are farther away will produce a smaller output, so the tonal structure of each chord can be varied.

Looking down from the top, the three reed plates are seen slightly hidden by the capacitive electrical pick-offs. Several of the reeds are seen to be broken off. Since some of the broken reeds were found in the machine, they were probably not broken off intentionally. It may be possible that all reeds were originally tuned and used.

From the spectral analysis of the tone from each reed, along with the measured amplitude of each tone and the physical distance between the pick-off to the to the tone reed, the amplitude contribution of each reed is estimated.

Several other very low-amplitude frequencies were seen in the spectral analysis of the notes. These could have been power-line harmonics of 60 Hz, which were seen, lingering notes from previous chords not quieted by the dampers, or distortion in the amplifier or recording equipment.

Our best guess is based on the remaining reeds, and the distances the capacitive pick-offs from the reeds.



Pick-off reeds shown above the tone reeds.

The musical chords

Based on our best guess of the tones measured from the electrical output signal, the components of each cord, along with its approximate frequency and musical interval are listed.

Most of the chords comprise thirds, fifth and octaves. However a few anomalies seem to have crept in, such as in the E chord with a diminished third and a strange F#5 in the C chord. These may have been deliberately introduced, or the result of damage or age of the chime machine.

Historically, after Richard Ranger produced the first chime machine, the musicians at NBC adjusted the device to produce more pleasing notes. The details are unknown, but one change noted was the addition of a capacitor across the electrical output, which would have the effect of attenuating the higher frequencies. Note that the chords do not have the same harmonic mixtures that a xylophone has, where the overtones are in general not harmonically related to the fundamental notes. Whether the original tuning attempted to imitate a xylophone we do not know.

	Note	Frequency	n	Chord
G Chord	G3	196.0	-14	Fundamental for G Chord
	B3	246.94	-10	Perfect third above G3
	G4	392.0	-2	One octave above G3
	D5	587.33	5	Perfect fifth above G4

	Note	Frequency	n	Chord
E Chord	E4	329.0	-5	Fundamental for E Chord
	G4	392.6	-2	Diminished third above E4
	E5	659.26	7	One octave above E4

	Note	Frequency	n	Chord
C Chord	C4	261.63	-9	Fundamental for C Chord
	E4	329.63	-5	Perfect third above C4
	C5	523.25	3	One octave above C4
	F#5	739.99	9	(strange note)
	G5	783.99	10	Perfect fifth above C5

Sidebar: The Equal-Tempered Musical Scale

Music is based on frequencies in a *scale*. One in frequent use in Western music is the *equal-tempered* scale. Here, the musical octave, where two notes differ in frequency by a factor of two, is divided into 12 semitones, each tone a fixed frequency fraction above the previous one.

The notes in the equal-tempered scale are related to each other by the relation

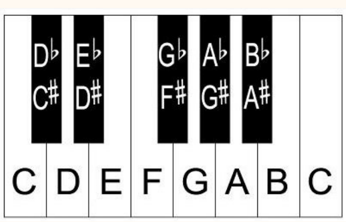
$$f\,(Hz) \;=\; 440 \;\cdot\; \left(2^{n/12}\right)$$

where middle A has a frequency of 440 Hz. The notes in the scale differ by a *semitone*, and the number of semitones is the difference in the value of *n*.

The notes are given name, such as A4 for middle A, at a frequency of 440 Hz. Each tone is 5.9463% higher than the preceding one. The notes are given name, such as A4 for middle A, at a frequency of 440 Hz. Each tone is 5.9463% higher than the preceding one. The distance of the notes from middle A is the value n, starting at zero for middle A.

Blending of two or more frequencies forms musical *chords*. Musical chords sound the most pleasing to the ear when the frequencies are in ratios of small numbers. Examples of these ratios have the names "perfect third" when the frequency ratio is 5:4, "perfect fifth" when the ratio is 3:2, and the octave where the ratio is 2:1. In the equal-tempered scale, fifths and thirds are not exactly in ratios of 3:2 and 5:4, but close, and produce a slow beat note. The equal-tempered scale allows music to be transposed to any set of keys on a piano, for example, as the ratio of the spacing between the notes is preserved.

Perfect fifth chords have notes that differ by n = 4, thirds by n = 7, and octaves by n = 12.



The perfect thirds and fifths in the equal-tempered scale are not in the exact ratio of 5:4 and 3:2, however. The ratios are 1.2599 instead of 1.2500 and 1.4983 instead of 1.5000. This results in a slow beat between the notes, which, to some ears, enlivens the chord.

If you have a keyboard, play the C, E and G notes, which contains thirds and fifths and listen to the blend of the notes.

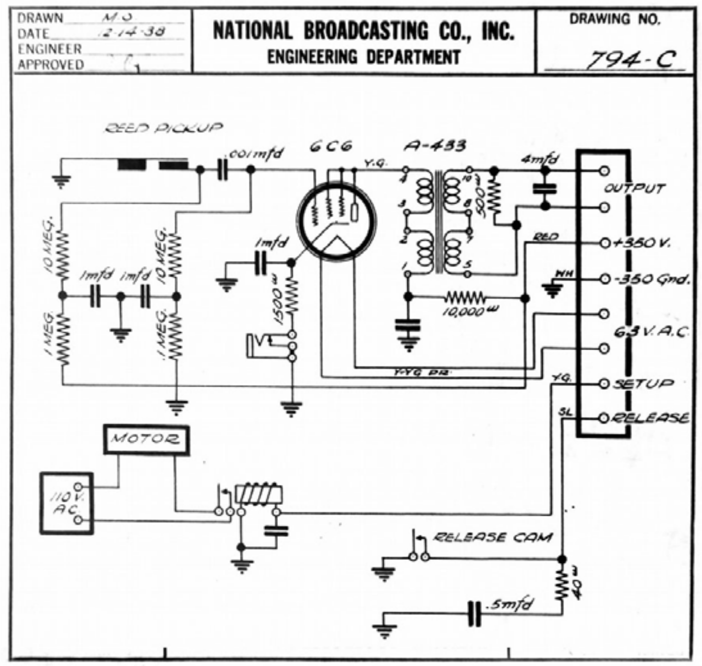
A Portion of the Scale

Notes	n	Frequency (Hz)
C3	-21	130.81
C#3	-20	138.59
D3	-19	146.83
D#3	-18	155.56
E3	-17	164.81
F3	-16	174.61
F#3	-15	185.00
G3	-14	196.00
G#3	-13	207.65
A3	-12	220.00
A#3	-11	233.08
B3	-10	246.94
C4	-9	261.63
C#4	-8	277.18
D4	-7	293.66
D#4	-6	311.13
E4	-5	329.63
F4	-4	349.23
F#4	-3	369.99
G4	-2	392.00
G#4	-1	415.30
A4	0	440.00
A#4	1	466.16
B4	2	493.88
C5	3	523.25
C#5	4	554.37
D5	5	587.33
D#5	6	622.25
E5	7	659.26
F5	8	698.46
F#5	9	739.99

The electronics

As mentioned earlier, the output sound is not produced acoustically, as in a music box, but electronically with capacitive pick-offs.

The higher modes will not couple strongly to the capacitive pick-offs, so each reed is expected to produce only one significant signal, the fundamental mode. Thus the octave overtones seen are not produced by a harmonic of a lower-frequency reed, but by separate, individual reeds, or possibly by harmonic distortion in the electronics.



Amplifier and motor circuits.

All the capacitive pick-offs are tied together and sensed by one vacuum-tube amplifier.

The 6C6 amplifier tube is triode connected, with the control grid connected through the 0.001uF capacitor to the pick-off bar, insulated from the case and charged to 350 volts.

When the reeds vibrate, their capacitance to the pick-off electrodes varies which induces an alternating voltage on the input to the 6C6 amplifier.

The amplified signal is transmitted through the output transformer in the plate of the 6C6. The signal level is suitable for introduction into the studio equipment.

Our recordings were taken with a voltage of 70-150 volts to the anode of the amplifier tube, as well as the polarizing voltage to the pick-off electrodes. The unit is designed to operate with up to 350 volts to the tube and the pick-off electrodes.

A relay controls the motor. A momentary switch halts the turning of the plucker drum after one revolution.

The NBC chine machine, serial number 2, is being preserved in original condition and is once again operational. CHRS is honored to have this valued historical artifact and will display it prominently in the museum.

References

(1) The NBC Chimes, by Bill Harris: www.radioremembered.org/chimes.htm
(2) NBC network maps 1935 & 1937, from John F. Schneider: www.theradiohistorian.org/nbc3537.htm
(3) The NBC Chimes Museum by Michael Shoshani: www.nbcchimes.info
(4) NBC Radio City, by John F. Schneider: www.theradiohistorian.org/radio001.htm
(5) The NBC Chimes Machine, by John F. Schneider: www.theradiohistorian.org/chimes.htm

The Authors

Dr. John Staples, W6BM, designs and builds particle accelerators at the Lawrence Berkeley National Laboratory. He received his Extra Class ham license and First Class Radiotelephone and Radar licenses in 1958. Besides being an avid collector of vintage electronics, he has been a passionate motorcyclist for over 50 years.

John Stuart, KM6QX, is a CA Licensed Mechanical and Control Systems Engineer. He had a 35 year career with PG&E in San Francisco doing design and construction projects on 500,000 volt substations and 36" transmission pipelines; primarily in the instrumentation, measurement, and control fields. After retiring from PG&E, he worked 14 years for San Ramon Valley Fire as a radio technician and facilities engineer. His interests include ham radio and measurement instrumentation. ◊