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# RADIO NEWS

JULY

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The Electrical Future of Music

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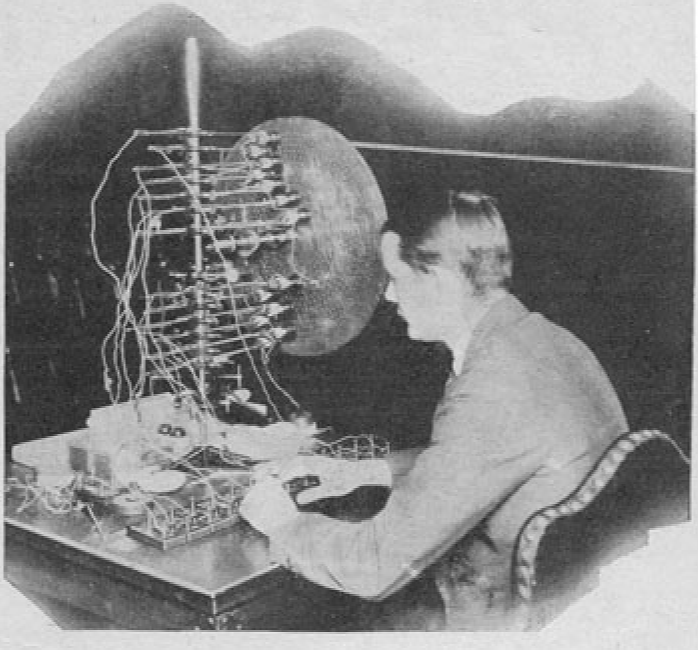
# *The Electrical* FUTURE



One new instrument is the photo-electric organ, devised in the E. E. Free Laboratories. The keys light small lamps which shine through the holes in the rotating disc

WHEN historians of science come to assay in future centuries the contributions of radio to civilization it is not improbable that one of the chief items to radio's credit will be that it brought together the art of music and the science of sound. There have been in every generation a few outstanding physicists who have been also musicians, like Professor Dayton C. Miller, who is an accomplished expert on the flute, Professor Vladimir Karapetoff, who is a distinguished pianist, or Dr. William Braid White, who adds to his wide competence in physical science an equal experience in musical criticism. But such men, in general, make of music merely their avocation. It is the service of radio science that it has brought professional physics and music together.

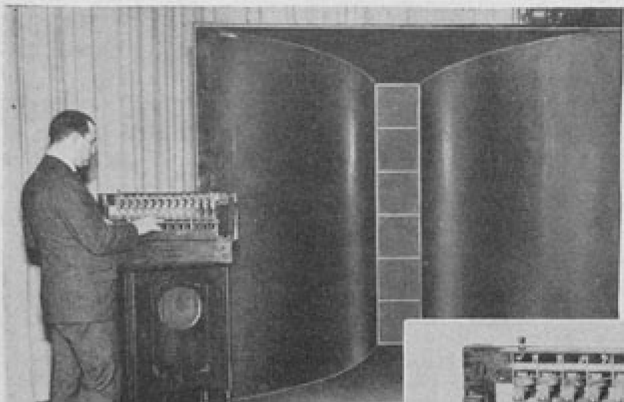
### *Union of Music and Science*

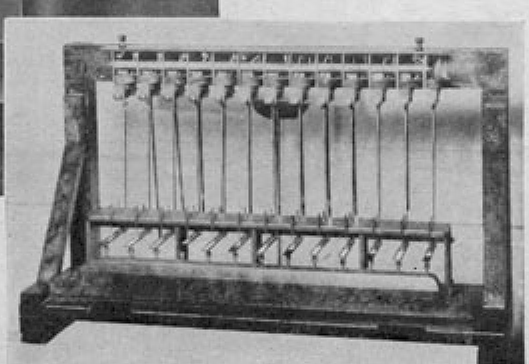
The talking motion picture and the electric phonograph are outstanding examples of how this union of music and science is going on at the moment. Even more intimate relations are in prospect, as no unbiased observer can doubt, through the perfection of the many types of electrical musical instrument which now are under development in more than a score of laboratories all over the world. Even the radio engineer and in some degree the radio listener not interested in engineering have been forced by their interests in this subject to learn much more concerning the physical basis of music than was known even to professional musicians a generation ago.

Most of our modern knowledge of this physical basis of music rests upon the pioneer investigations of the famous German physicist, Professor Hermann Ludwig Ferdinand von Helmholtz, the same who developed the well-known Helmholtz resonators for sound analysis, who made good use of the manometric flame as another analytic device and who presented for the first time on something approaching a firm foundation the theory of how the human ear detects the difference between different sounds. Based upon von Helmholtz's researches, a single musical tone or similar sound usually is said to possess three separable physical characteristics. First is pitch, representing merely the number of vibrations a second. Second is loudness or amplitude, which represents in physical terms the amount of pressure created by the sound wave on the ear drum or any other detecting device. In modern visual pictures of sound waves, like those produced by an oscillograph, loudness is represented by the amplitude of the curve above and below its median line.

The third of the von Helmholtz characteristics of musical tones is quality, and it is about this that there have raged, these past few decades, the most violent arguments. What the musical physicist calls quality in an individual tone is related to what the radio fan means by the same word applied to the perfection of broadcasting or of reproduction, but it is not quite the same. By radio quality one means such tone character as correctly represents to the listener's ear what the same listener would hear were he actually present in the broadcasting studio. What the musician means by tone quality is really nothing but the physical composition of sound.

Very few musical sounds, if any of them, consist of one pitch only. In radio laboratories and elsewhere physicists manufacture for testing purposes what are called "pure frequencies" or "pure sine waves." This means merely that only one series of sound impulses exists, that these impulses follow each other with perfect regularity at a definite frequency, and that the alternation of sound energy back and forth between the extremes of the vibration follows the law of simple harmonic motion, which law is represented by the familiar sine curve. For physical purposes all this is



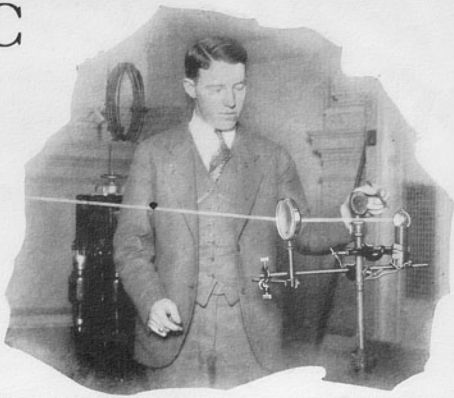


Dr. Alfred N. Goldsmith, of the Radio Corporation of America, demonstrating to the New York Electrical Society his electric carillon, shown at the right. Small hammers set steel bars into vibration, the tones being picked up magnetically and amplified

# *of* Music

*Fewer than one hundred distinct musical instruments have been invented in all human history— until electricity entered the field. Now there are dozens of new ones, with more to come*

*By* E. E. Free, Ph.D.*



The receiving end of the photo-electric organ. Interrupted light rays from the rotating disc at the left enter the photo-electric cell and are converted into musical tones

quite important. In music it is negligible. What it would make is a tone of a single pitch only, without any other variation whatsoever. Musicians are unanimous that such tones, when laboriously produced by physical apparatus, are "thin," "uninteresting" and generally unpleasing for musical purposes.

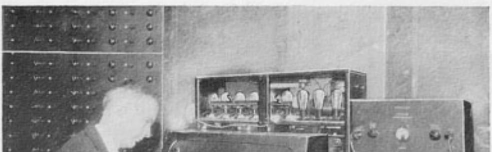
When a great violinist plays, for example, the tone of A on his violin he produces, as the chief of the sounds emitted, a vibration in the neighborhood of 400 cycles a second. However, the characteristics of the vibrating string and of the sound box of the violin are such that the emitted tone contains, in addition, a large number of other frequencies or pitches. These are variously called harmonics, overtones, and so on. They are represented on an oscillograph curve by relatively small ripples superposed on the simple sine curve which would represent a pure tone at the pitch selected. It is these accessory tones, whatever they may be, which determine the audible differences, for example, between the note A played on a violin, on a piano, on a trombone, on the human voice or on any other musical instrument. This it is that determines, Helmholtz and many other investigators have established, what the musician calls the quality of the tone.

All this would be much easier to understand were it possible to oust altogether from the science of music all such terms as "quality," "timbre" and the like, substituting for these metaphorical expressions a word which represents the simple truth. That word would be *composition*. Actually, every characteristic of any musical sound may be represented by this one word.

*E. E. Free Laboratories, Inc.

What is the composition of the sound? An analysis of this composition would consist, of course, of the familiar "frequency spectrogram"; that is, a curve which has pitch or frequency for its horizontal axis and which represents on its vertical axis the amount of energy on each frequency which is present in the tone. This is entirely analogous, of course, to the familiar color spectograms of the science of optics. Vastly more progress would be made both in music and in the science of sound if everything else were forgotten and all sound characteristics expressed in this single, simple way. Indeed, vastly greater progress *is* being made in this fashion, for it is now coming to be conventional in acoustic laboratories to represent the characteristics of sounds of all kinds by frequency spectrograms of this sort.

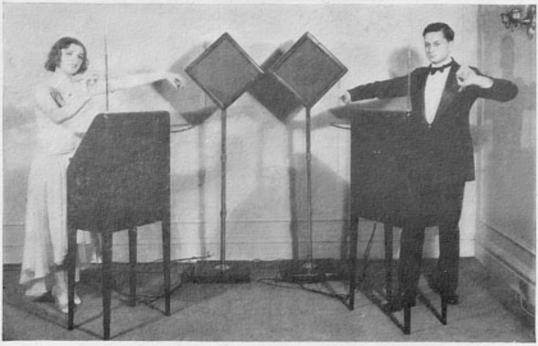
In the case of a violin tone, for example, the frequency spectrogram would indicate a high point at the frequency or pitch corresponding to the chief tone being sounded. Other lesser peaks of the curve would be presented at other frequencies corresponding to the harmonics or other tones, but these terms "harmonics" and so on could well be spared from modern acoustics.



Shown above is an electric organ in the laboratories of the Westinghouse Electric & Manufacturing Company. It is energized by vacuum tubes. Mr. R. C. Hitchcock is seen seated at the console; at his left is the large control panel

All this nomenclature of "fundamentals," "harmonics" and the rest is an inheritance from the days when the mind of the acoustic expert was fixed primarily upon the character of the vibrating object, like a string or a bell rather than upon the character of the sound wave itself.

Probably it is impossible to wean the science of musical sounds suddenly from its habit of talking about fundamentals and overtones and harmonics. Nor is this necessary. What is necessary is that the modern student of acoustics realize clearly that the thing which really expresses what he wishes to know is the frequency spectrogram and that is an expression of the physical composition of the sound. Musicians, of course, cannot be expected to use the word composition, as this means, for them, a totally different thing. There is no reason, however, why the frequency spectrogram should not be adopted and understood in music just as it is in mechanical acoustics, in the study of city noise or in any other branch of the science of sound. Once



**The Theremin, an electric musical instrument invented by the Russian physicist of that name, operates by controlled oscillations in a vacuum tube circuit. One hand moves to and from a vertical rod, controlling the pitch of the note. The other hand, moving up and down above the horizontal loop, controls the loudness**

In this chemical viewpoint of music each "musical element" resembles each chemical element in being individual and unalterable in nature. That is, each single musical element has its own pitch just as each chemical element has its atomic weight, its internal vibrational characteristics, and so on. One of the two chief practical differences in the two cases is that the "musical elements" differ but slightly from adjacent ones in the series. A tone of 400 cycles per second, for example, may be thought of as shading gradually into the adjacent tones of 399 cycles and 401 cycles. The same is true, it may be remarked in passing, between chemical elements, and one of the important modern discoveries is that there may be many types of a single chemical element, differing slightly from each other, and that these types may grade into each other or even may bridge the gap between two distant elements by steps which are almost insensible. Nevertheless, it remains convenient for the chemist to regard his elements as individual, separable species, and it would be similarly convenient, I am convinced, for us to think of musical frequencies in the same separate fashion.

this fact is accepted there is an interesting and stimulating analogy between music and another science—that of chemistry. In the science of chemistry all varieties of chemical compounds are thought of as composed of different numbers of atoms of 90 known elements. Water, for example, contains two parts of the element hydrogen and one part of the element oxygen. Hydrogen peroxide is composed of the same two elements but in different proportions—two of hydrogen to two of oxygen. All of the hundreds of thousands of chemical compounds that are known and the uncountable millions of such compounds that are known to be possible are built up in this same way out of definite relative amounts of the 90 definite elements.

In what might be called "musical chemistry" the composition of a musical tone may be thought of similarly as built up out of definite quantities of a definite series of "elements." These musical elements are the individual pitches or frequencies—256 vibrations a second for one C of the piano keyboard, 512 vibrations a second for the C one octave above this, and so on. Just as the composition of water or sugar or common salt or any other chemical compound may be expressed in the percentages of the elemental frequencies contained in it.

Just as is true of the real science of chemistry, so this "musical chemistry" has its two chief branches of analysis and synthesis. The analysis is the drawing of the frequency spectrogram. Within the last few years the art of radio has provided important new methods for this kind of analysis, with unexampled progress in practical acoustics in many fields. Musical synthesis, analogous to synthetic chemistry, includes the numerous recent attempts to put together tones, electrically produced or otherwise, in the various modern varieties of "modern synthetic music" like the music of the photo-electric organ, of the Theremin and of other devices of similar type.

Just as the tool of chemical analysis has been responsible for much understanding of the world around us, so the tool of musical analysis is uncovering the real nature of existing music. And as synthetic chemistry has provided the world with innumerable new and valuable materials, so synthetic music is destined, it may be agreed, to provide the musical world with tones, production and effects previously undreamt of.

The actual separation between two "elements" should be fixed, of course, at the approximate discriminating ability of the average human ear. For practical purposes it is sufficient to regard each one-cycle step as an elemental separation. That is, a tone of 399 cycles is one element, a tone of 400 cycles is another, a tone of 401 cycles is a third.

This indicates at once the other important difference between the "musical elements" and the chemical ones. The chemist recognizes but 90 separate elements, with two additional places for elements still unfound, bringing the terrestrial list to a total of 92. The musical physicist must enlarge this number to at least 10,000, one for each one-cycle step from the lowest musical tones approaching one cycle a second to the highest of musical importance, which are something over 10,000 cycles a second. However, since we are less concerned with the detailed use of this viewpoint than we are with the improved understanding which the viewpoint (*Continued on page* 70)

**L. M. Cockaday, Editor of RADIO NEWS, playing what is probably the world's only sound-proof piano, constructed so that all the sound of the piano could be picked up by a microphone inside the case for electrical study or loud speaker reproduction**

# The Electrical Future of Music

(*Continued from page 36*)

gives, this multiplicity of the musical "elements" does not seem a serious fault with this chemical analogy. And the analogy does provide a very simple way of studying musical tones and thinking about them.

There remains, however, the important matter of the value or utility of different musical "compounds"; meaning by a musical compound merely any possible combination of the musical "elements."

**Dr. William Braid White, acoustic engineer of the American Steel & Wire Company, testing the voice of Countess Olga Albani, radio singer, by pictures of the sound waves thrown on a screen**

One musical compound, for example, is the tone of the A string of a violin, containing perhaps 95 per cent. of one "element" (the so-called fundamental) and smaller percentages of other "elements," representing the so-called harmonics or over-tones. Another and more complicated "musical compound" would be the mixed tone produced at any instant by a symphony orchestra; the composition of which in musical chemistry doubtless would include hundreds or even thousands of musical elements each indicated by the percentage in which that element is present in the total tone.

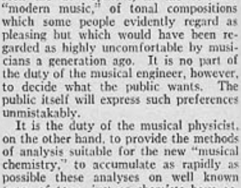
On this basis there would be no physical distinction between musical sounds and any other sounds. The noise of a passing street car, for example, would be represented by a frequency spectrogram and a "formula" in musical chemistry, precisely as one would represent the tone of an orchestra. Of course the two spectrograms and formulas would be different, but there would be nothing, in the physical analyses themselves, to distinguish between the noise and the music.

This distinction is one about which physicists and musicians argue interminably among themselves. About the only real distinction, it seems to me, is the conventional one that the "musical sound" is, in any country and any age, the sound which is pleasing to the majority of people. Country and age need to be considered because it is obvious that Chinese music, for example, has a very different "chemical composition" from Occidental music and yet proves highly pleasing to the Oriental ear. One of the great mysteries of "musical chemistry" at present is that of just which "compositions" of musical tones are pleasing and just which are unpleasing, and why.

In a sense this problem is like that of the synthetic chemist who has produced in his laboratory a thousand new chemical compounds. Some of these may be highly useful to mankind and to industry. Others will be disagreeable and harmful. Still others will be useless or inert. There is but one way for the synthetic chemist to decide which of his new compounds fall into the useful class. That is to try them. Similarly, it is probable, there will be but this one way of actual trial in which the synthetic musician can decide which of his tone compositions are pleasing to the average person. Furthermore, all this is likely to change.

Within the past twenty years we have seen the development, in the so-called "modern music," of tonal compositions which some people evidently regard as pleasing but which would have been regarded as highly uncomfortable by musicians a generation ago. It is no part of the duty of the musical engineer, however, to decide what the public wants. The public itself will express such preferences unmistakably.

It is the duty of the musical physicist, on the other hand, to provide the methods of analysis suitable for the new "musical chemistry," to accumulate as rapidly as possible these analyses on well known types of tone, just as chemists have accumulated chemical analyses on well known types of rock, and to provide, in addition, the synthetic machinery by which new musical "compounds" may be produced. This article would be expanded beyond any possibility of the Editor's patience were I to attempt to outline the thousands of analyses already made, indicating the different characteristics of the tones of different instruments or of tones from variable instruments like the human voice.



**C. A. Johnson, of the E. E. Free Laboratories, with a special electro-magnetic pick-up used to take the tone from a single square inch of a piano sounding board**

There is but one thing which perhaps requires attention. The invention of the piano had upon the art of music the most powerful effect of any event until the modern development of electrical music. This effect was the adoption of what is called the equi-tempered scale.

As I have explained above, the whole

(*Continued on page 71*)