

# ELECTRO-MECHANICAL INSTRUMENTS

History by  
Tom Rhea  
Originally  
published  
between  
1975 & 1981

The earliest use of electricity to make music was in electrically driven acoustic instruments such as DeLaborde's Electric Harpsichord (1761). And some of the first discoveries in electrically *produced* sound happened accidentally, as when in 1837 Dr. C.G. Page inadvertently discovered the principle of the electronic tuning fork while experimenting with magnets and coils. In 1885, Ernst Lorenz patented an instrument in which an electromagnet alternately attracted and released small metallic bars.

**The Telharmonium.** Against the background of these and other early experiments, the electric music system designed and built by the American Thaddeus Cahill (1867-1934) is the *tour de force* of early electric musical instruments. Cahill's designs were predicated on three 19th Century technological developments: 1) the overtone theory, as demonstrated by Helmholtz some five years before Cahill's birth, which theory indicated that a complex tone may be produced by summing individual sine waves (simple tones with no harmonics); 2) the development of electric generators (alternators or dynamos) which were known to produce alternating current in a sine-wave pattern; and 3) the newly invented telephone, which acted as a transducer that converted sound into corresponding fluctuations of electricity that could be transmitted by wire and reconverted into sound by a telephone receiver.

Cahill reasoned that if the output of an alternator were connected directly into a telephone receiver a simple tone would be produced. The pitch of this tone would correspond to the frequency of the current produced by the alternator. Cahill also knew that alternator frequency could be controlled in several ways, including regulating the speed at which the shaft of the alternator is turned. It was apparent that the outputs of many alternators could then be thrown onto the line using switches connected through mechanical linkages to a modified organ keyboard. With many such alternators and an elaborate switching system using several miles of wiring, one could create the complete harmonic series for each key on the keyboard and adapt the stops on the console for regulation of the volume of each harmonic. It would then be possible to combine all of the various alternator outputs used in a single line using transformers, thereby creating at the telephone receiver complex tones whose timbres were under complete control. The use of dynamos and the

telephone receiver gave rise to the descriptive names "Dynamophone" and "Telharmonium."

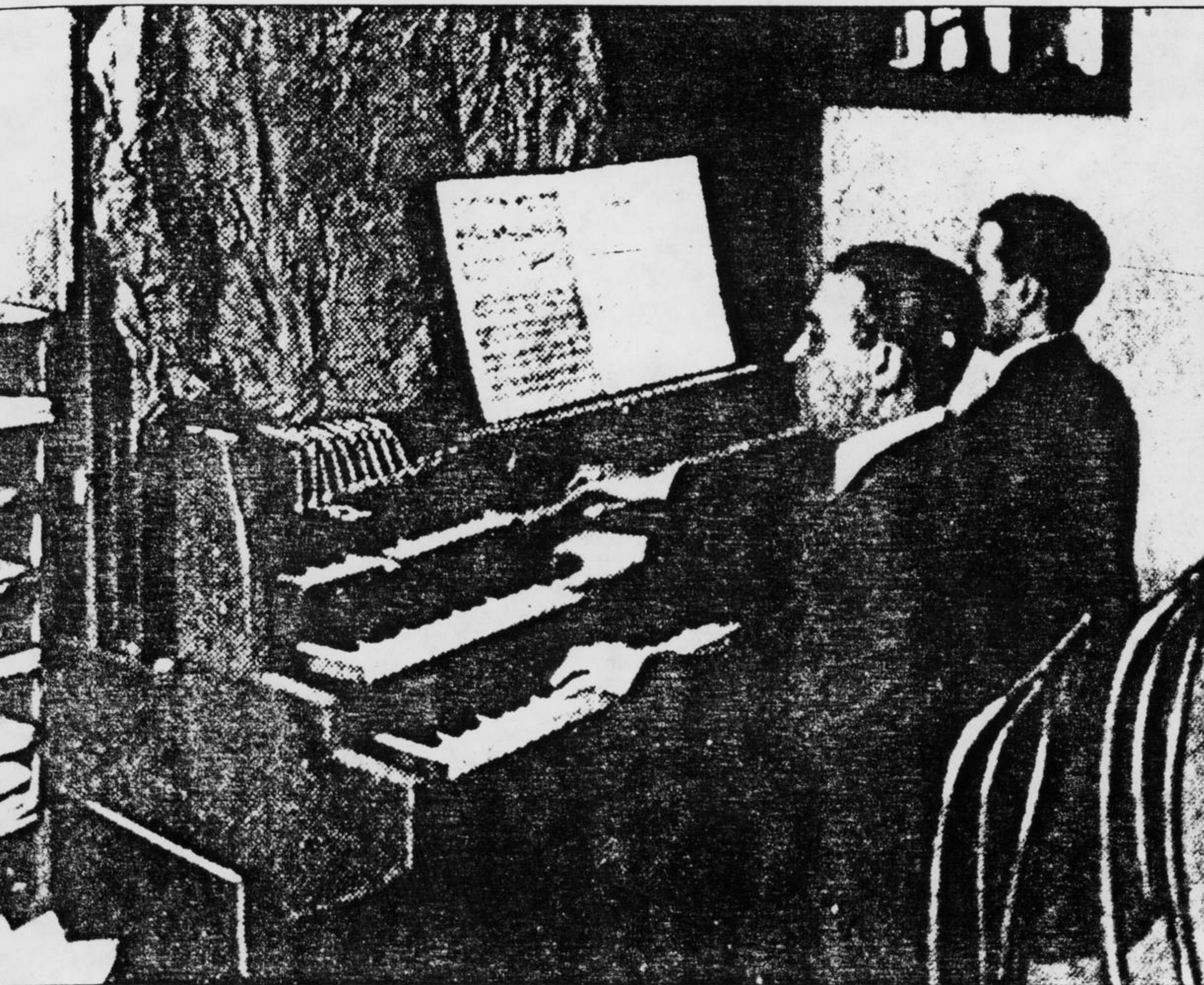
If all of this is starting to sound a little like a Hammond Organ, it should. Laurens Hammond extended and used most of Cahill's ideas some 35 years later. So why didn't we have the Cahill tone-wheel organ in 1900? Primarily because Cahill's design preceded some important technological developments. Lee DeForest's "audion" (triode tube), which was the basis of the vacuum tube amplifier, appeared the same year (1906) that Cahill completed an advanced model of his Telharmonium. Within ten years, Dr. H.D. Arnold and others at Bell Telephone perfected the amplifier to the point where it could be used on transcontinental telephone circuits.

Because Cahill didn't have amplifier technology, the Telharmonium was a roadie's nightmare. Judging from photos and patent descriptions, it weighed in at several hundred tons, and required a dozen railroad cars to be moved. These gargantuan dimensions were dictated because the instrument was designed to produce from twelve to fifteen *thousand* watts for each rotating element, without benefit of amplification.

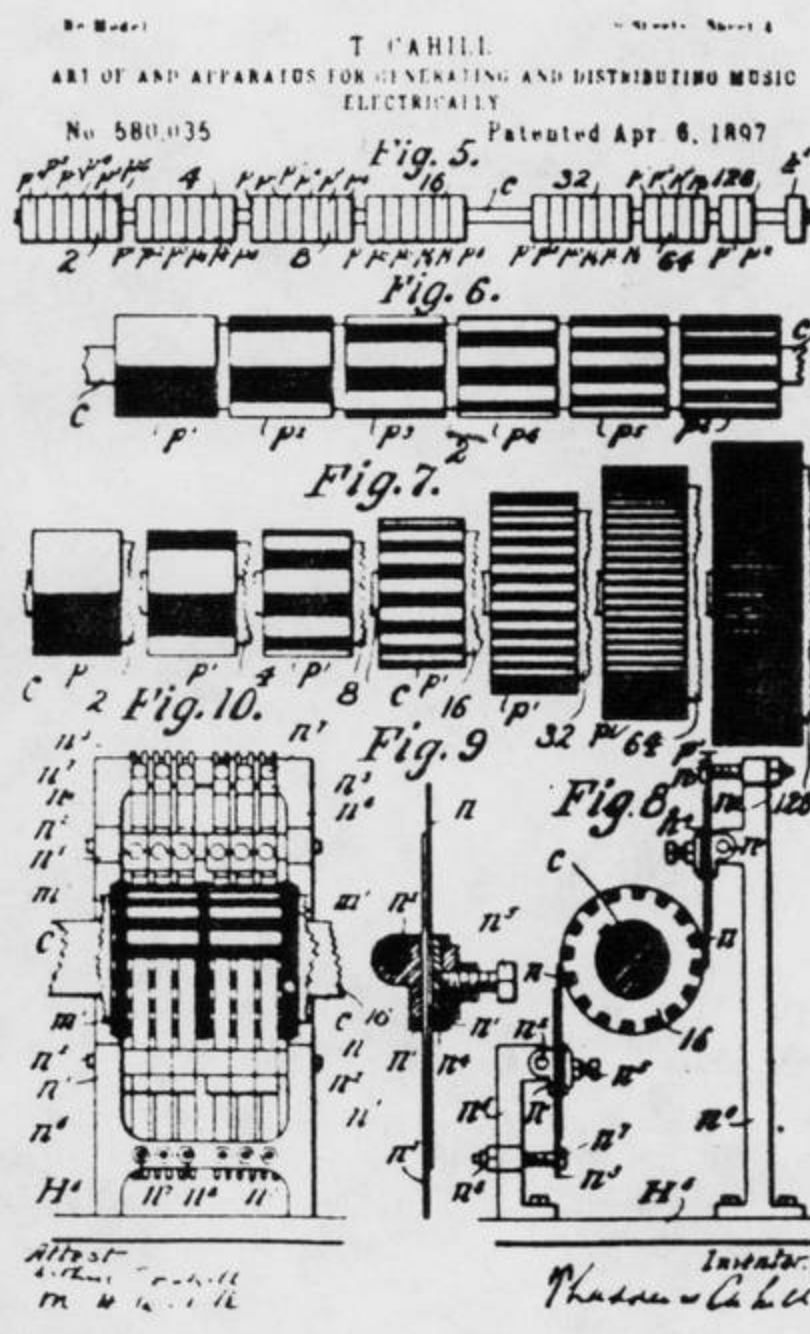
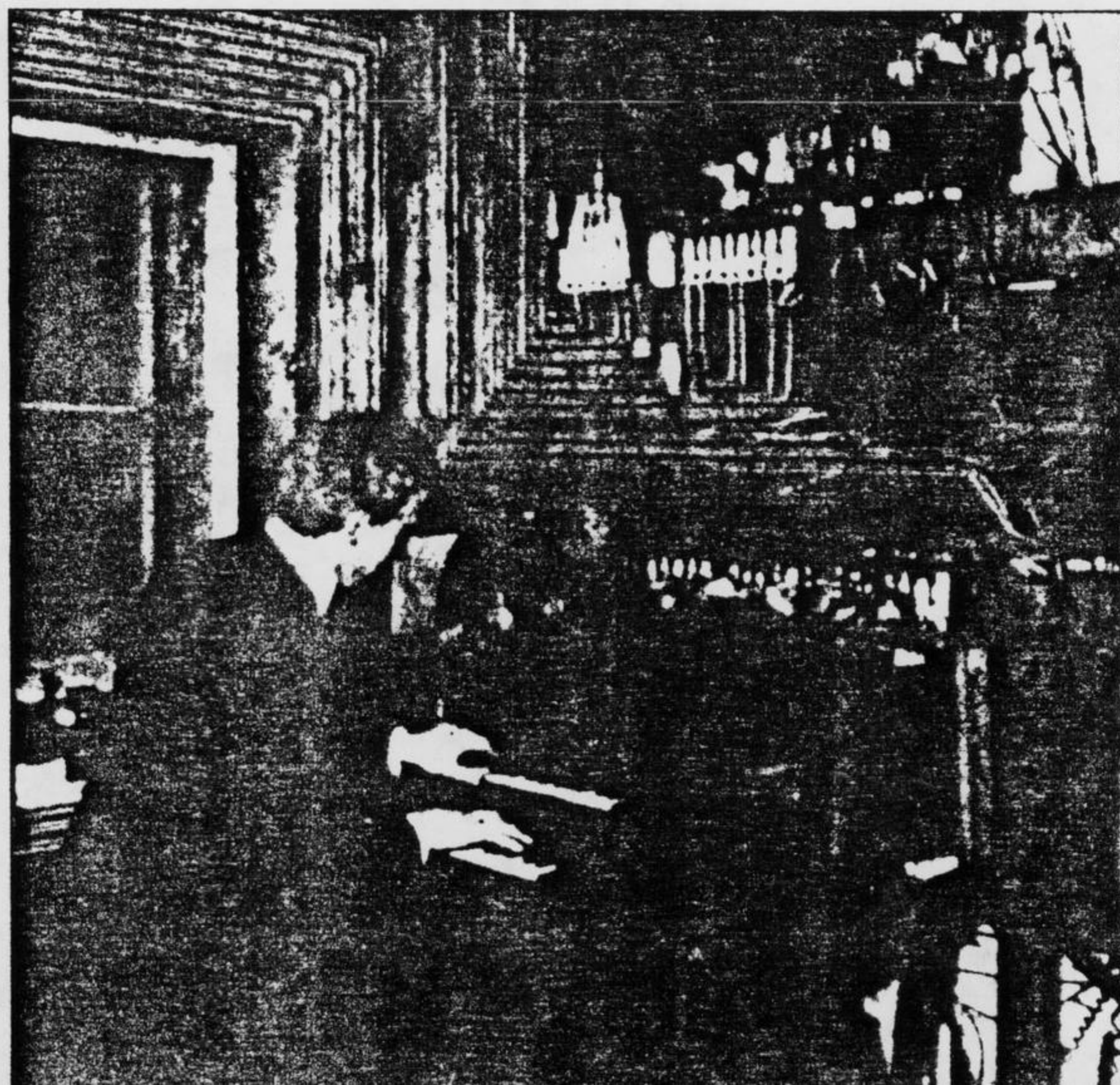
Of course, Cahill had no idea of mass-producing the Telharmonium. He envisioned a network of telephone wires that would distribute "Telharmony" to thousands of distant subscribers. The Telharmonium was our first Muzak system!

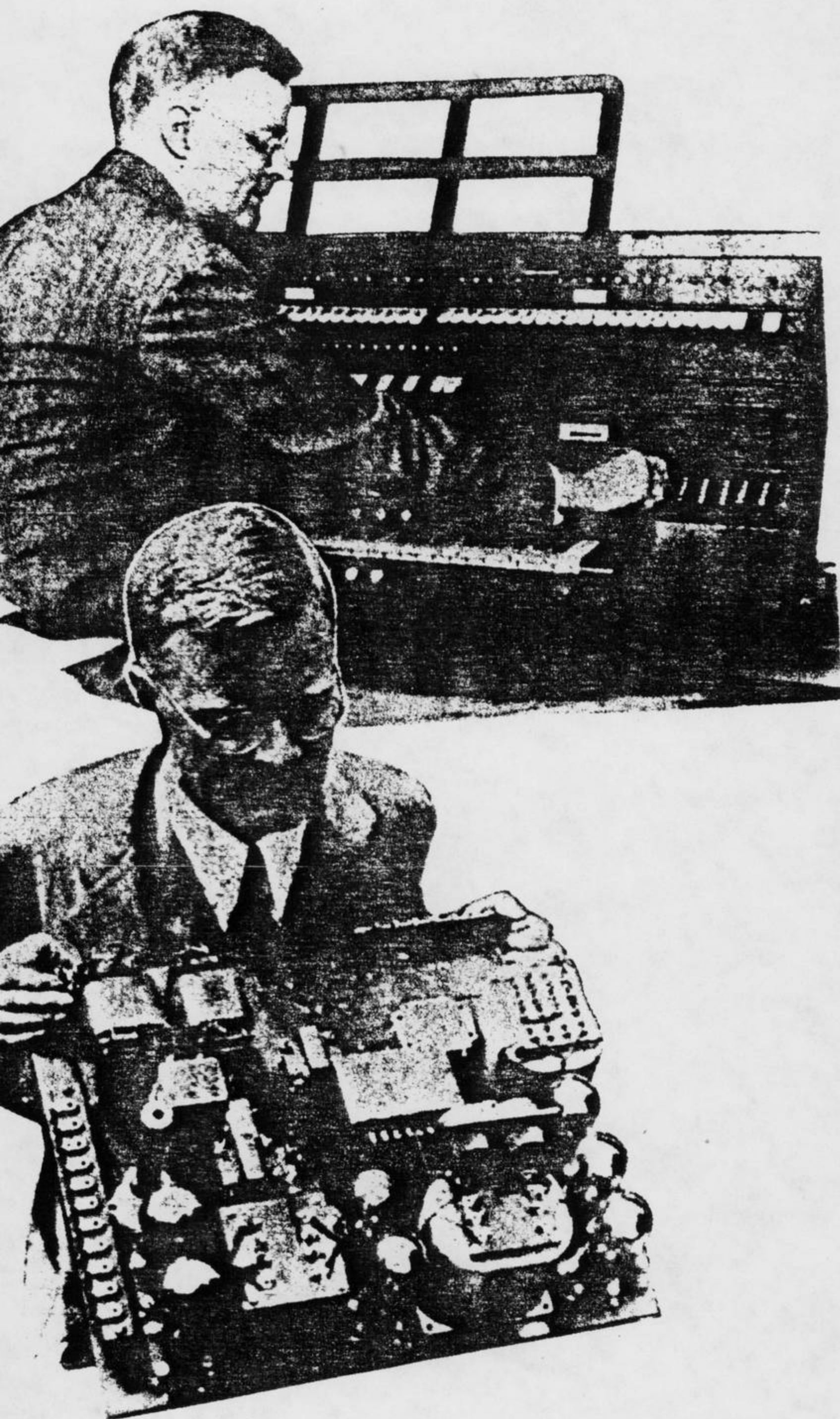
Cahill's earliest models produced electrical signals not with alternators, but with simple rotating tone wheels or "rheotomes," that had alternate sections of conducting and insulating material. These tone wheels served to regularly interrupt an electrical circuit, creating alternating current. The complex waveform produced was smoothed to approximate a sine wave by filtering through successive inductances. Individual rheotomes were grouped with a fundamental frequency and up to seven overtones, comprising a "rheotome cylinder." Seven each of these rheotome cylinders (tone generators) were grouped on twelve long shafts, thereby producing the equal-tempered scale through seven octaves. A motor-driven system of pulleys which differed in diameter in the same ratios as the frequencies of the scale was used to rotate the twelve "pitch shafts." C# rotated slightly faster than C, and so forth.

Of particular interest in Cahill's early Telharmonium model was the keyboard mechanism. Through a complicated electro-mechanical action which eventually brought



Performers at the Cahill Telharmonium, c. 1906. Bottom left: Cahill Dynamophone. Bottom right: Telharmonium patent diagram.





two coils into relative degrees of proximity, the loudness was varied dynamically. An electrical instrument with a touch-sensitive keyboard, designed before 1900! It is interesting to note that the *interface* between man and machine has been the subject of concern for instrument designers throughout the history of electric musical instruments. Designs come and go, but the value of giving the musician *control* over sound in the performance situation has been recognized from the beginning.

Thaddeus Cahill was a rare designer who combined a talent for invention with the legal expertise to patent his ideas and the business acumen to interest investors in his turn-of-the-century instrument. It was virtually an electric power *generating plant*, with dynamos rotating at the frequencies of the musical scale.

The prototype Telharmonium with 35 rotating rheotome cylinders was developed in Washington, D.C., during 1900 and electric music was "distributed" by telephone wires in the area. These demonstrations attracted investors who made it possible for Cahill to complete a more sophisticated model in Holyoke, Massachusetts. Among the technical improvements in the latter model was the introduction of a gear-driven alternator (dynamo) system for tone generation, providing more accurate intonation. The speaker system was also improved so as to avoid the "shouting" of some notes encountered with earlier speakers.

From the performer's standpoint, an important feature of the new model was the multiple keyboard console, which could produce several tone colors simultaneously. Several pitch manuals and a pedal could be programmed for different tone colors using switches to govern various harmonics. Swell pedals afforded variable and independent loudness control over these manuals. In addition, a small "dynamic" manual was provided to allow instantaneous loudness changes. Cahill stated that two performers were necessary to master the console.

The summer of 1906 marked the commercial debut of the Telharmonium; demonstrations were made by wire at the Hamilton Hotel in Holyoke, about a mile from the plant. Media descriptions stressed the "fullness, roundness, and pureness" of the tones. Some reporters felt that Cahill had realized utopian predictions of music in the year 2000. Others hailed the Telharmonium as the harbinger of "democracy" in music, since fine music could now be delivered to "... towns, villages, and even farmhouses up to a hundred miles or more from the central station."

Spurred by these rave reviews, Cahill packed up his instrument — on several railroad cars — and moved to Telharmonic Hall in New York City. In September the doors were opened to some 900 members of the New York Electrical Society for the first public Telharmonium concert. Officers explained that the plant had power to supply fifteen or twenty *thousand* subscribers, and that plans were underway to supply four circuits with different

kinds of music. The concert included several "classical" transcriptions, imitations of instruments, sound effects such as the passing of a drum and fife corps, and several vocals with Telharmonium accompaniment. It was another round of success for Cahill's heavyweight.

Although the outlook seemed bright and patronage was at first encouraging, the venture failed due to its own flaws before fledgling radio even had a chance to scuttle the music-by-wire concept. Evidently, Telharmonium wires wreaked havoc with normal telephone service due to the strength of the signal they carried. Cahill was beset with technical and legal difficulties, and many potential subscribers lost interest. Perhaps the Telharmonium would have failed in any case. As one of the performers noted, "In spite of the variety of tone colors available, the instrument itself had its own special character which pervaded everything, and which in time grew highly irritating to the nerves."

**The Gnome.** Even though the Telharmonium was not a commercial success, Cahill should be recognized as the pioneer in early electric music. The general principles he developed were successful later in rotating-wheel electronic musical instruments such as the Rangertone and the Hammond Organ.

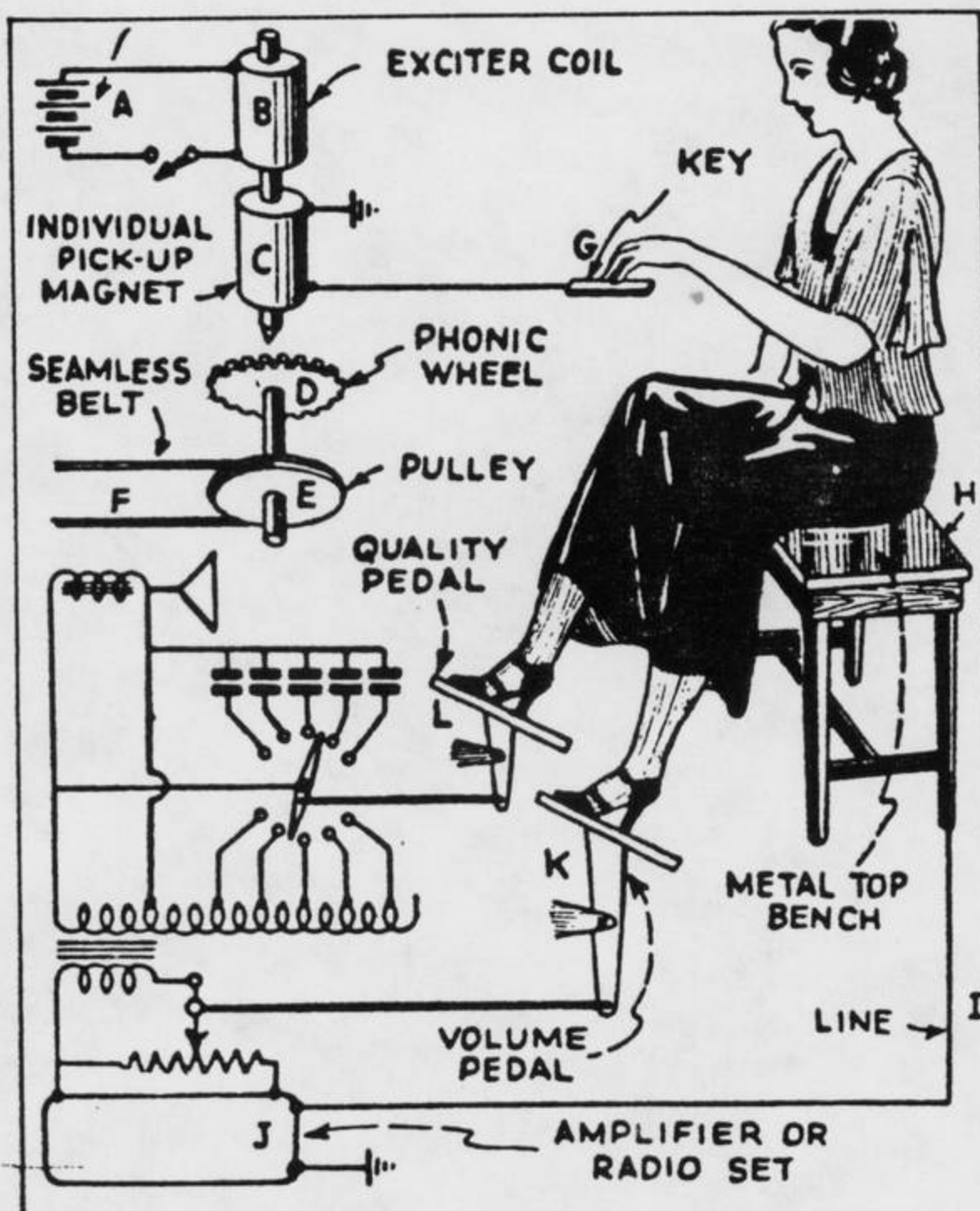
Many instruments whose design is based on Cahill's have components which consist of iron disks with indented edges which are mounted on a shaft and arranged to rotate in front of an electromagnetic pickup. The pitch depends on the number of indentations and the speed of the rotation. The waveshape (timbre) produced approximates the pattern of the indentations. Many builders have used this design or variants of it; of particular interest are the instruments built by Ivan Eremeeff and R.H. Ranger.

Eremeeff constructed several electromagnetic instruments during the early Thirties, using several techniques discussed in a magazine article which appeared in 1932:

The larger instrument is a synthetic type, operating on principles involving the synthesis of fundamental frequencies with harmonic, sub-harmonic, multiple, and fractional frequencies, for the production of musical tones of predetermined pitch, volume, and tone quality.

This is a description of additive synthesis, the creation of complex tones through the mixing of simple tones (sine waves). In contrast to this, the following passage describes an instrument utilizing subtractive synthesis, the modification of a complex tone using external circuitry, e.g. a filter:

The smaller instrument, called a Gnome, works on the same basic principles employed in the larger instrument. The Gnome produces tone quality with the aid of a dial wave-alteration control, in which waveforms are modified by the selective connection of the output circuit to differ-



**Mechanism for Gnome, c. 1932. Opposite: Richard Ranger and the Rangertone organ, c. 1933.**

ent taps of a transformer, or by a system of condensers which are adjusted by dial.

The Gnome had touch-sensitive immovable "keys" made of metal. The performer sat on a metal plate which made the body act as part of the circuitry! Expression devices included a volume pedal, a tremolo pedal, and a sustain pedal which controlled the final release of the tone. Particularly with Eremeeff's instruments, we are again struck by the early designers' interest in providing nuance with expression devices under the direct control of the performer.

**The Rangertone.** Another early electromagnetic instrument was the Rangertone Organ (1933) developed by Richard H. Ranger. This instrument had some 50,000 separate circuits, and according to the inventor, a home model would have cost \$5,000 — in 1931 dollars! An unusual feature of the instrument was the amplifier-selection tone color system. The Rangertone had separate amplifiers that acted as individual channels when chords were played on the keyboard. The keyboard was split, and the highest three notes played by the right hand were routed to separate amplifiers; the lower keyboard had a similar arrangement. Thus it was possible to produce six notes with different tone colors by filtering the output of each amplifier independently. Separate tremolos were also possible.



**Laurens Hammond seated at his modernized version of the Cahill Telharmonium, the Hammond organ, c. 1937.**

Public demonstrations and a radio debut of the Rangertone produced euphoric reviews. An example:

No longer is the composer limited to the tones of traditional instruments. He can now specify timbres. What will become of the orchestra? Perhaps a quintet seated at keyboards and controlling electrical devices will take the place of an entire symphonic organization. Perhaps a new type of virtuoso will arise, a Paderewski and a Toscanini fused into one super-performer who deals with a thousand horsepower instead of a hundred musicians.

The prediction of the demise of the orchestra was premature. Doubtless, Richard Ranger had no such intentions or delusions. Nor did the reviewer think to ask as simple a question as, "What happens to the individual tone colors of the Rangertone *when the lines of the music cross?*" Musical imperatives must dictate the design of electronic musical instruments, just as they have the design of acoustic instruments.

Historically, there has been a perennial fascination

with the 'keyboard-as-orchestra' concept. But given one brain and one pair of hands, a single performer just can't act like a hundred people.

**The Hammond Organ.** The father of the Hammond Organ may have been a clock. At least, the tone-wheel Hammond Organ is driven by a synchronous motor similar in design to the motor of the electric clock that was the first product of the Hammond Company. The secret of this clock's accuracy was the motor which *synchronized* its speed to the closely-regulated frequency of electric current (60Hz in the U.S.). The same principle that made the Hammond Clock more accurate made the Hammond Organ more pitch-stable than its contemporaries that had vacuum tube oscillators.

Laurens Hammond's tone-wheel organ was based on the modernization of Thaddeus Cahill's designs for the Telharmonium. The Hammond Organ was made suitable for mass production by the mechanical simplicity of the

design and the miniaturization made possible through use of vacuum tube amplifiers. This made it possible to have silver-dollar-sized tone wheels in place of Cahill's huge whirling dervishes. The early (A) model Hammond Organ had two manuals and pedals, a tone generating system with 91 iron disks driven in pairs on a common shaft by the synchronous motor, and a drawbar system that facilitated the production of many different timbres.

The Hammond Organ had its public debut in April, 1935, at the Industrial Arts Exposition in Radio City's RCA Building. On the way there, sales manager Emory Penny stopped in Detroit to give a demonstration for the company's first customer — Henry Ford. The New York demonstration was greeted enthusiastically by many who took their turn at the keyboard: Pietro A. Yon, organist at St. Patrick's Cathedral; Fritz Reiner, conductor of the Chicago Symphony; and George Gershwin, who immediately ordered one for his own use. As the story goes, when Gershwin got his Hammond home, he found the "lost chord" on it. But he got up to answer the phone and couldn't remember the registration when he returned!

The Hammond Organ had a significant impact on pop music almost immediately. In 1935, Milt Herth became the organist at radio station WIND in Gary, Indiana. He helped to establish a new style of playing. As a Hammond Company brochure put it:

Herth's staccato style of playing the Hammond on WIND and other radio stations caught on quickly and became the distinguishing characteristic of his work. His "Stomping At The Savoy" recording in 1936 was the first of many discs that helped build his fame as a leading entertainer in theater, radio, and nightclubs.

Another well-known performer on the Hammond Organ was Ethel Smith, a frequent performer on the "Hit Parade" and "Hit Parade Of Old Time Tunes" on radio. She specialized in Latin-American styles, of which, in a 1944 interview published in *Etude* magazine, she said:

Latin-American music had long intrigued me, especially the rhythms, and believing the Hammond was particularly adapted to playing this music, I made a trip to South America to study it firsthand, adding Portuguese to my college Spanish. In eight months I had collected a number of examples of the samba, rumba, tango, and conga, and found that the Hammond lent itself particularly to these sparkling rhythms. It was while playing at the Copacabana in Rio that I was offered a radio contract in the United States, and returned to accept it.

Since that time, the parade of professionals who have used the Hammond Organ is very lengthy. For many years, "electric organ" and "Hammond" were practically synonymous. But the Hammond Organ Company was called before the Federal Trade Commission in 1936 for having the audacity to call their instrument an *organ*!

Hammond versus the FTC is a classic episode in the

history of electricity and music; a story that continues to have implications today. When Laurens Hammond introduced his organ in 1935, he said that it shouldn't be compared with any other instrument; that it had a "voice of its own." But in 1938, the FTC ordered the Hammond Company to cease and desist from representing that its Hammond Organ "produces the entire tone coloring necessary for the rendition, without sacrifice, of the great works of classical organ literature"; that "it covers the entire range of musical tone colors"; that "any tone that is a sustained tone can be produced on this marvelous instrument"; and that "an infinite variety of tones, covering the flute, diapason, string, and reed families, are instantly available to the organist."

No one, including the Hammond Company, would make these claims today in behalf of the instrument. In fact, the Hammond Company had already dropped these advertising phrases by the time the FTC ruled. The ruling was actually a victory for Hammond, since it vindicated their use of the word *organ* to describe the instrument.

Today, an organ is an organ is an organ. But in 1936, pipe organ manufacturers insisted that the new Hammond gadget could never be called an organ; they suggested it might be called an "electrotone" to avoid confusing the public. During the court battles that ensued, there was a great deal of talk about the "faulty" harmonics of the Hammond, which were based on the equal-tempered scale. There were arguments concerning the construction of the human ear, and tests using tone analyzers that yielded complicated oscillographs.

The furor reached its zenith when a Hammond organ was pitted against the \$75,000 Skinner pipe organ in the chapel of the University of Chicago. Nine experts and fifteen University of Chicago students, the latter picked at random, were marched in for the test. Thirty selections were played, some on the Hammond and some on the Skinner; the panel was asked to tell which instrument was being played. The experts averaged about ten mistakes apiece, while the students came out about 50-50. The importance of the event lies in its *occurrence*, not in the interpretation of the results. However, the laws of probability do indicate that the students' judgements could have been duplicated by tossing a coin!

Beneath the smokescreen of talk about the debauchery of the word *organ*, there was some hard economic reality. The peak year for the pipe organ industry in this era had been 1927. By 1935, when the Hammond was introduced, there had already been a decline of some eighty percent in pipe organ sales. The electrical intruder was economical, portable, and reliable. Pipe organ makers were feeling the pinch. Some five thousand Hammonds were sold in the first three years, and about 35% of these went into churches. As is often the case, the new instrument soon created a new market, and found its own position without displacing its predecessors.