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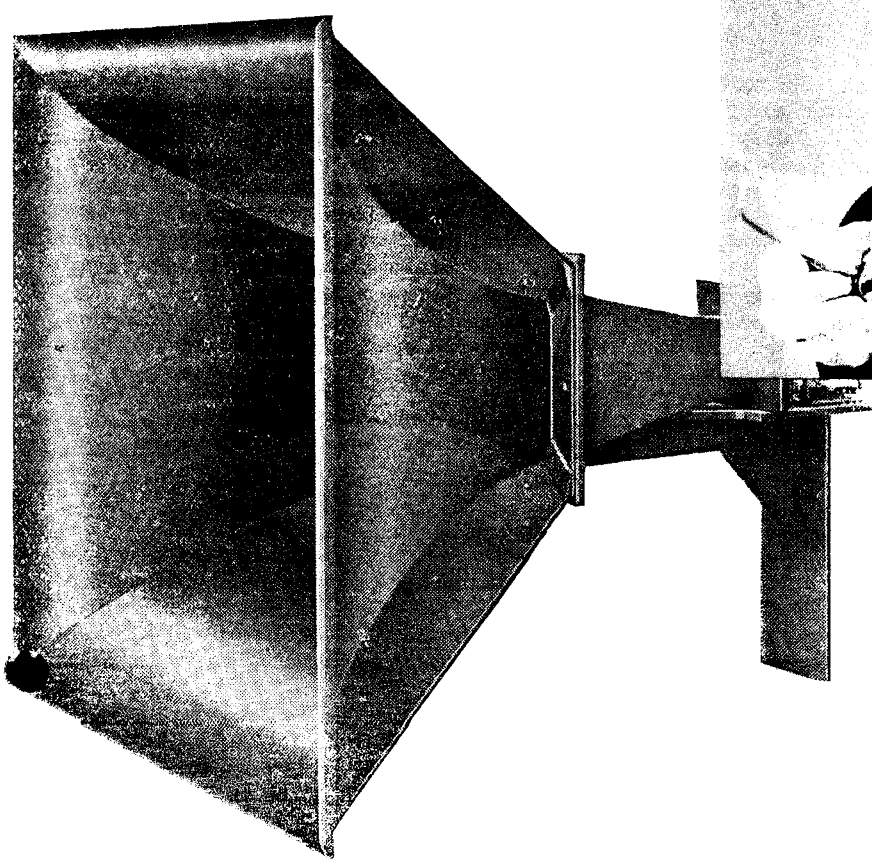

An Interview with P.G.A.H. Voigt

Part One

by BRUCE C. EDGAR

Introduction

I was talking with our Editor Ed Dell about horn loudspeakers when he mentioned the British audio pioneer P.G.A.H. Voigt. Ed had received Voigt's address from Geoffrey Wilson during a chance meeting in London, outside a car rental agency in Heathrow. Prof. Wilson was returning to the U.S. after his father Percy's funeral. Since Percy Wilson was one of the most outstanding and venerable of English audio authorities and a horn enthusiast—it was natural that Paul Voigt's name should come up. The brief interchange elicited a letter from Wilson, without which our contact with Voigt would not have been possible. Ed supplied Voigt's address in Canada, and in April, 1980, I wrote to him about his tractrix horns. In August *Mrs.* Voigt wrote to me; however, since her letter covered none of my questions, I called Voigt, and this was the beginning of many letter and telephone exchanges.

Ed and I asked Voigt if he would allow me to interview him for *Speaker Builder*. At first he refused, saying he had too many projects and immediate worries to deal with. But he gradually relented, and we planned the interview for January, 1981. However, over Christmas he developed a painful hernia which required surgery, and we postponed our meeting.

During January, while awaiting the surgery, Voigt wrote several long letters on many of the speaker subjects I'd been asking about. He went into surgery on February 3; all seemed to go well, and he came home five days later to recuperate. But on February 9 he suffered a heart attack and died.

Mrs. Voigt sent me all the letters he'd been working on. It seems to me, from their volume, that he sensed his time was running out and wanted to "set the record straight." So I have edited them and other material to create the "interview" Voigt in person was never able to give us.

Fig. 1. The young Paul Voigt (with earphones) demonstrates a reflex (dual high and low frequency) amplifier circuit for the Wireless and Experimental Association of Peckham in 1922.

Paul Gustavus Adolphus Helmuth Voigt was born on Dec. 9, 1901, in London, England, of German parents who emigrated and became naturalized British citizens in the late 1800's. His father was a buckram importer; his mother, says Paul's widow Ida, was the "real brains of the family" and a constant source of encouragement to her son. She lived to be 103, and Voigt expected to emulate her.

Paul Voigt's approach to loudspeaker design was to use intuitive physical reasoning, in the style of many researchers of the early 1900's. Though he had many friends he was a loner who persisted towards a goal of audio perfection in the face of contrary contemporary thought and wisdom. Peter Baxandall said of Voigt in *Audio Amateur* (4/79, p. 15), "He was a splendid chap....He demonstrated his corner horn loudspeaker. I heard that evening a standard of music reproduction I'd never heard before." He was a hero to many British audiophiles of the first half of this century, but relatively unknown in the U.S.A.

Voigt was an audio "systems" engineer before the term was invented. He developed and/or invented velocity and capacitor microphones, amplifiers, transformers, moving coil cutters and pickups, and horn loudspeakers, all for the quality reproduction of sound. By the end of his career he held 32 patents. In many areas he was ahead of his time, and by the time the world caught up with him, his contributions were either ignored or forgotten. So as you read this interview, see how many modern hifi concepts and ideas had precursors in Voigt's work.

SB: Where were you educated?
Voigt: I was a "born" inventor and for that reason wanted to learn engineering. My parents could afford to send

me to Dulwich College [a private high school], two miles from home. It had an engineering side. And so during World War I, from the age of 13, I was learning basics of engineering. In 1922, I graduated in Electrical Engineering from University College, London.

By then, with the war over, radio was permitted again. I was experimenting on the subject, and my first article appeared in *Wireless World*, Dec. 10, 1921, before I had even graduated. I wrote it when I was 19. [See *Fig. 1.*]

SB: What was your first job?

Voigt: My first paid employment was at J.E. Hough, Ltd., Edison Bell Works in 1922. They made gramophone records and plastic mouldings for the radio and other trades. The firm were afraid the B.B.C.'s advent would damage the record market, so they sensibly decided to enter that market themselves. I was one of those taken on to get the radio side started.

I knew I was an inventor. There was no way of knowing ahead of time how valuable my ideas might be, and employees were normally obligated to sign away their patent rights. But I insisted that my patents should remain my property (I to pay the cost of patenting), giving the firm preferential rights as regards licensing. There never was a better incentive to invent things of direct use to the company.

Apart from my work designing radios and test gear, etc., by late 1926 I had developed the first British-designed electric recording system to last for years under practical working conditions. Our competitors were ahead of us, only because they were using U.S.-designed equipment.

I had not been with Hough for long before I realized that if the artists and musicians played and sang as they did for the B.B.C., into a mike whose output was amplified and fed into some kind of electric cutter, then a better master should result than we could get from using an assortment of large trumpets. Hough encouraged me. And before the end of 1926 I had designed a moving coil cutter system which meant that records did not have the hysteresis distortion natural to moving iron devices. Hough put the system into commercial use and, with minor improvements, it remained in use until Edison Bell, Ltd., (the later name of the company) died in the slump in April 1933.

SB: Tell us about your early experiments with microphones.

Voigt: Although my initial function was to develop radio components and sets for manufacture, I soon became interested in electric recording. Just when that interest crystallized I cannot say without my notes, but a brochure entitled "The History of Edison Bell" shows a picture of the recording studio in which a swan neck horn Browns loudspeaker is clearly to be seen. I had it fixed there and was using it as a "backwards" mike. The electrical people had put in a connecting phone-type circuit to my lab, where I had a similar loudspeaker used in the right way. No amplification was needed, and while the speaker mike (perhaps the 120Ω winding) may not have matched the connecting circuit, that was short and the mike certainly matched the output speaker. At one time I tried carbon mikes, but the amplitude distortion made me scrap the idea.

SB: How did you build and set up your first good microphone?

Voigt: I had a portion of the wall between the studio and the lab removed and a shelf put across the opening. On that shelf I put a specially designed mike, which I'll describe in a minute, and I hid the opening with thin silk or something. The mike's square frame did not fit the opening, so I closed the space around it with strips of carpet. The face of the mike was in the plane of the partition wall, simulating a closed window.

From what I learned from the excursion requirements, any velocity operated mike, moving iron or moving coil, already had to be free to move about without any appreciable restraint. The ordinary arrangement of a diaphragm clamped around its edge was *out*.

The special mike's diaphragm was the size and shape of a saucer and spun of very thin aluminum. Tangential spokes from its edge met at the hub on the convex side. The curved diaphragm was suspended in a circular hole in a square frame with about ⅛" clearnace around its periphery, on two threads about 1½" long spaced about 45° either side of the vertical center line. To stop it from flopping about, two rubber threads pulled it down; each was at about 45° on either side of the lower part of the center line. I may have stuffed cotton into the clearance between the diaphragm and the frame.

The transducer part consisted of a flat elongated coil mounted with its plane vertical and on an extrapolation of the diaphragm spin axis. Using magnets (at first permanent magnets out of a magneto, but later we used an electro-magnet) fitted with poles that provided a plane vertical air gap, the end of the coil was located within the pole piece jaws and free to move. Thus as the diaphragm vibrated, the coil vibrated, inducing a voltage in that part of its coil within the magnetic field. This arrangement was not efficient, but as a mike it was easier to put in some amplification than to devise a freely supported circular coil and magnet system.

SB: How did you become interested in loudspeakers?

Voigt: We badly needed a good speaker to use in the studio. Musicians wasted much time in the recording studio because they could not tell from the gramophones in use at the time just how good or bad the recording was.

For laboratory test purposes, I wanted a perfect loudspeaker, or at least as close as possible. On April 30, 1924, when the B.B.C. was about 18 months old, Capt. P.P. Eckersley, an ex-Marconi engineer who was then the B.B.C.'s Chief Engineer, lectured to the Radio Society of Great Britain on how they coped with the B.B.C.'s early problems. I had already considered what perfect mono sound should be like if ever we could produce it, and in the discussion which followed the lecture was able to ventilate my hole in the wall theory. The lecture was reported in *Wireless World* of May 28, 1924, and the discussion in the next week's issue.

SB: Can you give a brief description of your hole in the wall theory?

Voigt: In those early days, I had done a mental preliminary survey, not of what bits and pieces should be put together to get good audio, but more fundamentally of what good audio would be like if we ever got it.

My 1924 answer was my hole in the wall theory, which was controversial for a long time. Some people thought perfect reproduction should sound as though the sound originated in the room you were in. This overlooks the fact that your room has one set of reverberations and the studio or concert hall a totally different one. The latter set can easily be made negligible by having the announcer come right up to the hole on his side of the wall and, as it were, talk direct to you through that hole. That theory and the consequent understanding of what to aim for has been fundamental to my outlook.

Incidentally, a non-technical musical expert, visiting a friend having a demonstration of my corner horn wrote up his experience for some musical journal without using the word "hole": he described his experience as listening through a window.

SB: What was the "state of the art" of gramophones and loudspeakers in the early '20's?

Voigt: When I asked leading gramophone designers what perfect reproduction would sound like, I found "forward" tone was apparently the idea. One of Edison Bell's slogans at the time was, "It rings out loud and clear," so we have a clue to 1920 ideas of perfect reproduction! Now, having some scientific knowledge, I could not quite understand how a mechanical instrument could be expected to produce a tone which would appear to originate at some point six inches or so in front of the mouth of the horn, unless this effect were achieved by resonance or some form of forward reflection which would give a focal point there.

In the 1920's loudspeakers for radio, etc., mostly began with an enlarged headphone mechanism coupled to a horn. The general idea had developed that the horn was the reason why the audio quality was so poor. I myself looked upon horns as an unknown quantity, with the introduction of extra resonances into the system as a most probable disadvantage. [*Editor's note:* This attitude changed rather drastically later.]

With my hole in the wall concept in mind, it was obvious to me that for bass it was necessary to provide for the free oscillation of air volume through any such real or imaginary hole; therefore the standard type of reproducer based upon the idea of a "blown up" earphone with trumpet attached would not meet the end requirements. Even the so-called hornless devices, with large diaphragms, were driven by some electromagnetic mechanism which would be inefficient if adjustable and adjusted to be well clear of the pole piece, and would collapse onto the pole pieces if too close. To prevent either occurence, the diaphragms had to be stiff, with no freedom of movement. After World War I I had seen a Magnavox with a 20″ or so horn and moving coil drive; but it sounded like the flat bottom of an enamelled army mug of those days. I do not suppose for a moment that its diaphragm *was* made out of a mug, but that's what it sounded like, and with an iron diaphragm clamped around its edge that is just about what you can expect.

FIG. 2

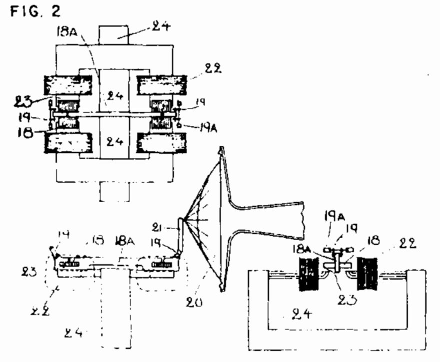

Fig. 2a. Early Voigt moving coil loudspeaker portrayed in a patent drawing. (British Patent #238,310.)

SB: What is your normal approach to research?

Voigt: My normal way of trying to achieve progress is to get to grips with a problem and work out the answer. Then I compare that answer with the established ideas when such already exist. If my answer fits the established ideas, then I have discovered I can safely use those ideas. If, on the contrary, my result does not fit the established ones, then arises the question: which is correct, or are both wrong?

Since I am rotten at math, my approach is rarely the mathematical one. The usefulness of math depends upon the accuracy of the assumptions on which that math is based.

SB: How did you start designing moving coil loudspeakers?

Voigt: At Edison Bell I was experimenting with moving coil systems. Using my knowledge, I designed the moving coil cutter for the recording system. I was familiar with the consequence of applying various magnetic field strengths to current carrying conductors.

One major result is that the greater the field strength, the greater the electromagnetic force for a given current. In those days undistorted audio watts were expensive; that was one reason for pushing up the flux density. Another was that the greater the flux density, the greater the electromagnetic damping on the moving coil (other things being unchanged). And there was a more subtle result, theoretical but partly imaginary.

Suppose you could make the field strength so high that the electroacoustic efficiency would average 100 percent over the whole audio scale, would it not have a flat energy response curve with no peaks or troughs? While 100 percent efficiency is unattainable in practice, there was no question in my mind that the nearer you could get in that direction the better

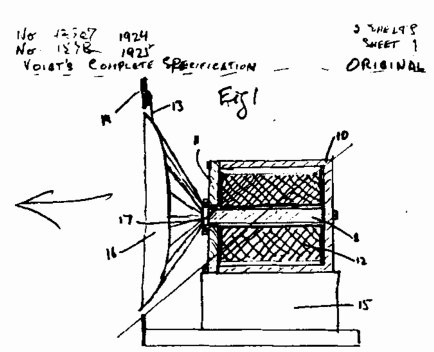

Fig. 2b. Voigt's original drawing of the moving coil loudspeaker which he had to remove because of the prior claims of Rice and Kellogg.

would be the ratio of average to peak. For example, if the average was one quarter of 100 percent, i.e., 25 percent, any energy peak beyond 6dB would provide the missing part for a perpetual motion machine!

The fact that in my lab I had both DC and AC mains meant that if I designed a huge magnet with electrical excitation, in those days when valve rectifiers were still unreliable, providing the excitation presented no difficulties.

SB: What did your first loudspeaker designs look like?

Voigt: I designed for high flux density on the electromagnetic moving coil drive. The company blacksmith provided a U-shaped soft iron core bent, as I recall, out of 2″ diameter bar. Onto its straight portions went four separate coils, each with a carbon lamp across it to take care of the "splash" when switching off, and so, for my earliest high power magnet experiments, I had a quarter kilowatt excited field U magnet to experiment with. In due time, I arranged for a pole-tip system suitable for a cylindrical coil. (In my school text book at Dulwich, such coils were called "Solenoids." Nowadays that word describes such a coil plus iron cores to operate switches, etc.)

In my case the coil actuated a lightweight saucer-shaped aluminum diaphragm, driven through aluminum spokes and supported so as to be able to move very freely. It was surrounded by strips of mother's old carpets to act as a non-resonant baffle.

You will notice that my diaphragms (see *Fig. 2*) are based on the "cap of a sphere" shape, with "spokes" tangential to the surface. I used this arrangement on the moving coil mikes I experimented with while developing the recording system, and on the early moving coil loudspeaker drives. It never went into production, as I had no satisfactory method of making the spokes adhere to the spun aluminum diaphragm. When the adhesive between the spokes and the diaphragm gave way, it would rattle under working conditions. When I had overhauled it carefully and had my moving coil system working, I would "turn up the wick" and alas, within five minutes it would be rattling again!

By the time the patent examiners had my complete loudspeaker specification under study, they were aware of the work of Rice and Kellogg. That anticipated my concept so completely that I removed from the complete specification and the claims any mention of the moving coil system. Such removal meant that manufactuie for sale was out, but not that I had to give up my hole in the wall concept or stop experimenting with moving coil systems.

SB: Was this your first patent application?

Voigt: No, I had six previous patents granted to me, all on wireless devices. I was eventually granted British Patent #238,310 for "Improvements to Sound Reproducers." That is the one which would have anticipated Rice-Kellogg if it had been two months earlier. My application date was May 20, 1924, so the Rice-Kellogg application should be in March of that year. I was quite unaware of their work at that time; the news had not reached Britain.

[*Editor's note:* Rice and Kellogg were American engineers working for General Electric who developed the first good electromagnetic moving coil loudspeaker[2] Kellogg's patent application was filed on March 27, 1924.]

SB: How did your first loudspeaker perform?

Voigt: When it was all ready for test, I was looking forward to hearing something vastly better than any previous loudspeaker. Upon switching on I was very, very disappointed. I had never had anything sounding so "tinny." The highs were strong and the lows very poor.

On thinking it out, I realized that when calculating the load into which I assumed the square inches of diaphragm area (piston equivalent) were working, I had used the mechanical ohms figure for a plane audio wavefront.

The disappointing result I was getting, I realized, was due to that assumption being approximately right for frequencies so high that the wavelength was small relative to the dimensions for the diaphragm, but totally wrong under reverse conditions when the diaphragm dimensions were small relative to the wavelength. Under those conditions, instead of reacting with back pressure when exposed to the peak pressure of low frequency sound, the air simply escaped sideways out of the compression region; and that happened in reverse during the suction half of the sound cycle.

Evidently, I had to find some means of preventing those lateral component motions, and that is how I came to design my horn. The obvious way to prevent lateral motion, is close to the diaphragm is to fit a large diameter pipe. But analysis of that obvious way shows that while the to and from flow of the air propagating the sound is prevented from lateral motion, it will propagate with a *plane* wavefront, at right angles to the inner surface of the pipe, until it reaches the end of the pipe. At that point it abruptly escapes transversely and thus a coupling takes place into an air resistance totally different to the mechanical ohms resistance at the diaphragm.

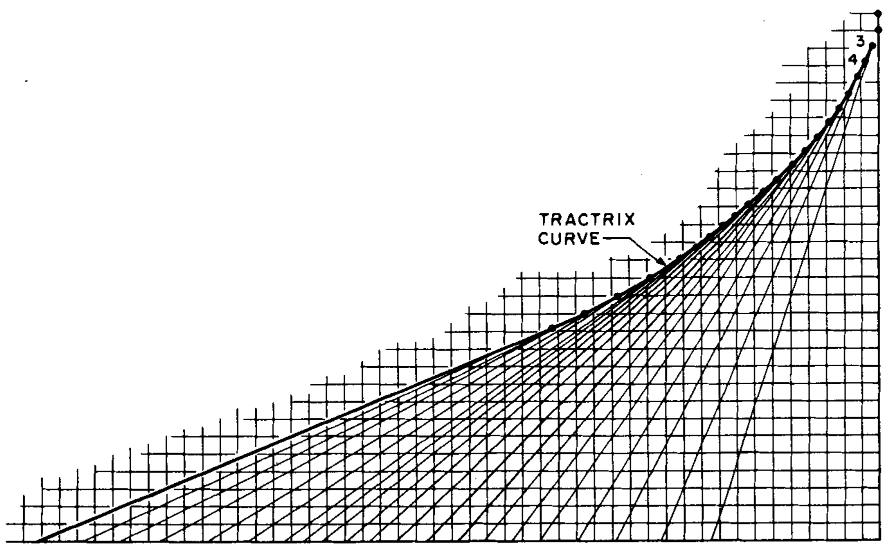

Fig. 3. Drawing of the Tractrix curve from Voigt's instructions.

The parallel pipe thus basically only transfers the discontinuity which permits the lateral "escape" near the diaphragm to a more distant location. It does not eliminate the discontinuity. What is worse, at the discontinuity a reflection analogous to that in a transmission line travels back to the diaphragm, and tends to make the pipe behave rather like an organ pipe!

SB: How did you make the transition from a pipe to a horn?

Voigt: Part of the "trick" necessary to improve the situation at the output end of the straight pipe is to scrap that shape and put a slight, expanding taper at the diaphragm end. If that taper is gentle enough the lateral motion can be reduced till it is too slight to introduce any major loss of reaction pressure.

In a pipe which tapers slightly outward, the sound wave will no longer travel with a perfectly flat wavefront. Where the wavefront travels along the surface of the taper, it will quite naturally travel parallel to that tapered surface and to the surface on the opposite side. Thus, the wavefront edges will diverge to fit the expanding taper, and the normal spherical expansion of a sound wave has begun.

As the area increases, its relation to the lower frequency wavelengths improves. This is beneficial when these wavelengths reach the end of the horn, but they have already suffered a little because of the poorer relationship near the smaller diaphragm. And, if the taper remains gentle, the wavefront will only expand slowly, making the horn inconveniently long if that benefit is to be preserved.

The practical solution is to increase the outward taper as the distance from the diaphragm increases. This too is desirable. We increase the taper gradually to a 90° angle to the axis, and if possible, place a flat baffle around the opening. Then by the time the wavefront reaches the opening, instead of an abrupt discontinuity it passes a rounded surface leading to the baffle, and the ill effects of the enclosure ending are greatly diminished.

SB: How did you draw the horn curve?

Voigt: The curve (see *Fig. 3*) is easily plotted on drawing-board paper by starting with deciding on the semimouth size at the 90° to the axis taper. Suppose that size is to be near 30cm. Place a rule at 90° to the axis and mark the approximate position of the mouth at 30cm from the axis (point *#1*). Mark clearly the first cm from that point toward the axis (point #2). Keep the lower end of the rule on the axis and move it along the axis, keeping the 30cm rule point near the clearly marked top cm. In fact, let the edge of the rule pass over point #2 (which is 29cm from the axis). When point #2 is at 30½ cm along the rule, step the motion along the axis and mark the next point, #3, at the 29½cm mark on the rule. This point will be some 28cm from the axis. Move the axis end of the rule along the axis again so that point #3 is at 30½cm along the rule and mark point #4 at 29½cm along the rule.

A curve will develop. Continue the above procedure. As the curve flattens out, the steps can be made longer. The curve we want is the curved line through the points.

As I drew out this curve to make the smoothest possible transition from the nearly parallel taper near the diaphragm, to a 90° angle to the axis, I wondered if I had re-invented the standard logarithmic (exponential) curve mentioned in some advertisements in the mid '20's. When I plotted the latter, I found that at the throat, where the taper was very slight, the difference was negligible. As I approached the mouth, however, the taper increased faster than the logarithmic curve, and the 90° was reached quite soon. Later I heard from our draftsman that the curve was known in the mechanical world as a Tractrix.

SB: How did you come to the conclusion that the wavefronts in a horn must be curved instead of flat?

Voigt: I was familiar with basic engineering principles. It follows from the most elementary of these, that where the edge of the wavefront rubs on the inside surface of the horn, the wave surface has no alternative but to orient itself at right angles, to that surface.

Try and imagine the pressure face of a wavefront endeavoring to propagate parallel to the axis. It will have to leave a gap between its own circumference and the expanding inner surface of the horn. The further forward that wavefront goes, the bigger will the gap become, and the wavefront will automatically spread sideways to fill that gap.

This sideways spread reduces the volume moving forwards and thereby slows it down. In time this slows down the wavefront, the effect being greatest where the gap is being filled and least at the furthest distance from the gap. With a circular horn, the expanding gap exists all around the circle, and the furthest distance available to the wavefront is in the middle, i.e., on the axis. Thus inevitably the wavefront will bulge forward. With a circular horn, that bulge will not be 100 percent spherical. This will surprise most readers, but it is not a serious matter.

To sum up: the difference between the tractrix and the exponential with its flat wavefront (theory) is that one was designed by a 24-year-old engineer familiar with the elementary mechanics of nature, the other by a skilled mathematician. Take your choice!

[*Editor's note:* On July 5, 1926 Voigt applied for a patent, and he was granted British Patent #278,098 for the Tractrix Horn in 1927.] ☐

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The Interviewer

Dr. Bruce C. Edgar is a Space Scientist for the Aerospace Corporation and is a Contributing Editor for Speaker Builder *in the areas of horn design and the history of loudspeakers.*

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Continued from page 9

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I might add that one or two of these would be a fine gift from the enthusiastic speaker builder. Most people are happy to have music in their kitchen or bedroom. As my friend and associate Eric Johanson once said, "Everybody needs loudspeakers."

My thanks to Larry Perault and Eric Johanson of Spectrum Loudspeakers for competent assistance, and to Murray Saffran for the fine photographs. My next construction project will be an uncompromising two-way system for about $70. ☐

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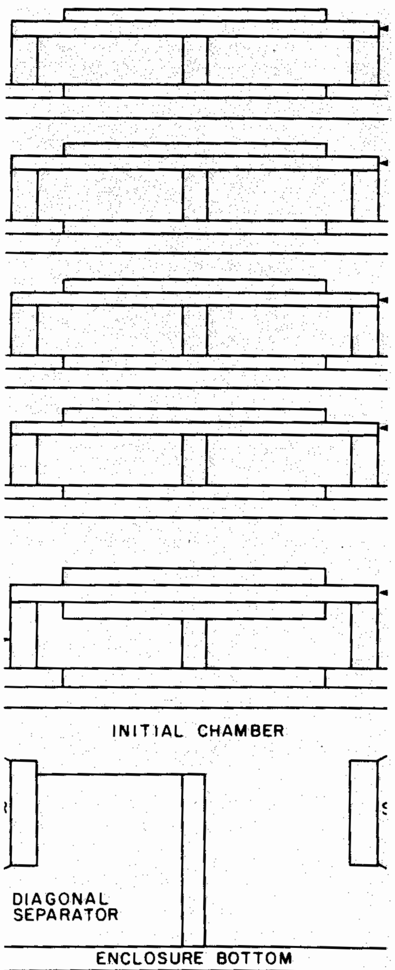
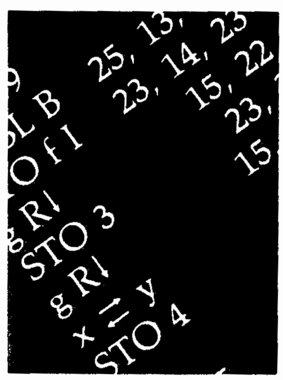


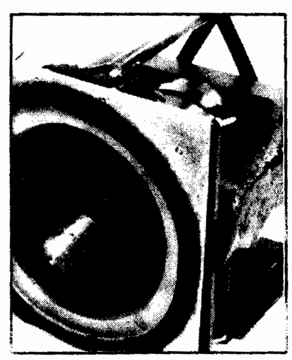
SYMMETRICAL AIR FRICTION ENCLOSURE

BUILDING FALCON'S MONITOR MINI



PASSIVE RADIATOR DESIGNER

VOIGT 2



Part II

An Interview with Paul Voigt

by Bruce C. Edgar

SB: *How big was your first tractrix horn?*
Voigt: My lab's first horn had a four foot square mouth and a four inch square throat, and was about five feet long with a monster magnet. Its frequency range peaked a little before its gradual low frequency cutoff, but now the sound was no longer "tinny," and the response went down to below 100Hz, being still useful at 50Hz.

My lab had a cathedral ceiling and left over from the radio set repairs who were the previous occupants, a platform onto which my monstrous loudspeaker could be raised. It provided the most perfect reproduced sound I had yet heard up to that time. In those days I did a lot of late work, so in the evenings, up to midnight when the B.B.C. dance music closed down, I had the pleasure of listening to reproduced live music, with no commercials, from London's leading hotels via the B.B.C.

This confirmed my belief that if a high average energy efficiency electricity-to-audio transducer could be produced, then not only would the energy response curve be smooth, but the audio effect would be very satisfying—assuming, of course, that the polar distribution diagram of the energy did not concentrate parts of the energy into compact beams with the listener located in an area of major concentration.

In my case, my four-foot-mouth horn speaker stood on a platform running across the room. The horn's axis was about nine feet above the floor; as I am only about 5′11″ tall, my ears were about three and a half feet below axis level. The wall above the entrance door was about four feet from the horn mouth, along the axis. So any normal listening to which I was exposed was either reflected off that wall or may have come off the back of the diaphragm and been reflected in different ways.

SB: *When did your tractrix horns reach public notice?*
Voigt: As regards the word tractrix in connection with horns, that did not reach readers of *The Gramophone* till the November, 1933, number which described a visit to the inventors' exhibition at which Voigt Patents, Ltd., had a stand (see *Fig. 4*).

SB: *How did you construct your cinema horns?*
Voigt: In the drawings I made for the carpenter, the forward flare part was four pieces of plywood bolted together on frames cut to the correct shape. The front was square, so the sections joined at an angle which from the front was 45° off the vertical. The front opening was four foot square while the assembly's rear opening was one foot square. To that could be bolted neck pieces of the length required for their input sources. Now the angle of the plywood pieces relative to each other was not 45° throughout, but varied along the length of the horn. So I figured out a jig to hold the wood at the appropriate shape; then by sawing vertically, the varying angle would come out automatically. But, the carpenter could not see the need for that at all. Obviously the angle was 45°, and he had been in the business for many years.

Well, when people know all the answers I do not waste time arguing with them: when I have alerted them I have done my bit. He learned the hard way that horns can look like 45° joints, but they are not. He had an awful job making it fit together.

The curves of those horns were based on the tractrix across the center section. This meant that across the diagonal the tangent would be longer, increasing toward the mouth where it would be 1.414 times the center line tangent. I made the horns square as a matter of woodworking convenience, and with serendipitous results; for if the discontinuity at the mouth at the centerline caused a reflection, that reflection would be ahead in time of the effect of the discontinuity at the corners of the mouth. With a circular mouth, all the effects of the mouth discontinuity get back at the same time.

Once I did have a circular tractrix horn made for outdoor use. The spun aluminum flare measured three feet at the mouth, and the unit was housed in a cast aluminum box with a side door. The spun flare was, I think, in two parts. It sounded awfully "horny" compared with what I was used to with my wood horns, but there may have been other reasons.

That throat was circular, my wood horns were square. With the latter you might get vertical and horizontal "eigentones" affecting the load on the speaker, but they would spread. With the very strong circular casting, any eigentone would be radial with a concentration at the center. Since the casting was so strong the "give" would have been negligible and so the damping would have been small. With the wood horns, the inch-thick rear frame and plywood frame out forward would have lots of give and no doubt be able to absorb energy.

The question of give is important. Where a resonance builds up and a wall gives, energy is bound to be absorbed; and so the trouble will not get out of hand. The aluminum spun flare lacked the give of the slightly curved ply on the wood. In fact, with some horns, I had so much give and vibration at some low resonances that I had to reinforce the sides to get the response up to standard.

SB: *What developments led to the formation of Voigt Patents, Ltd.?*
Voigt: In the 1920's, while at Edison-Bell, I learned enough about magnets to design high-flux-density loudspeaker magnets properly. Those design principles were discussed in detail in my British Patent #331,209.

Excited field speakers, made under my patent by Edison-Bell, supplied with 40 to 50 watts excitation power gave a flux density of 16,000 to 17,000 gauss across a 2mm. gap. They were used for cinema work, high quality public address systems, etc. Edison-Bell "died" in the slump (1933), so I started my own business to keep the speaker alive.[3] (See *Fig. 5*.)

SB: *How did you design your domestic corner horn? (Fig. 6)*

Voigt: The simplest way to visualize it is to imagine that my cinema square section horn, placed face down on the floor, is the bottom portion of a rather distorted pyramid. Then saw it into four parts by sawing vertically downwards from one corner to the opposite one. Now if you place one of the quarter sections into a corner of a room, the horn's performance will be unaffected.

SB: *How did the unusual reflector in the corner horn come about?*

Voigt: The next design problem I faced was obtaining an even distribution around the room. I knew the low frequencies coming from the horn would diverge, while the higher tones would be projected more or less in a beam. The high frequency beam would tend to strike the lower concave section, and the more divergent lower frequencies would be reflected by the larger concave surface. So I aimed at a 30° reflection up and down, so as to cover persons sitting, standing, or, of course, anywhere in between. [*Editor's note:* Voigt received British Patent #404,037 in 1934 for this feature.]

SB: *Why did you develop the λ/4 tapered pipe loudspeaker enclosure?*

Voigt: In 1933-34 I was very much concerned with trying to increase the amount of bass you can get with a fairly small cone. That cone was already driving a short horn, but the system was inefficient below the horn cutoff. Several cubic feet of space were available in the cabinet below the horn; the problem was to find a way to augment the lowest frequencies within the available volume. The method I finally adopted used a tapered folded pipe, rather like the neck of a horn, which exhausted near the floor. I named the system's bass department a bass chamber, but would certainly not have done so had I been aware of the impending introduction of what is now called the reflex cabinet, for that has a better right to be called a chamber than my more complex tapered folded pipe system.[4]

In those days any kind of a resonance was considered taboo, so I refrained from supplying any details. Its main purpose was to provide bass, and that I covered with the name bass chamber. [*Editor's note:* it even fooled Percy Wilson, technical editor of *The Gramophone*, who called it a Helmholtz chamber in his review[5] of the Voigt corner horn.]

Actually it behaves like the neck part of a very low frequency horn which stops before the flare is fitted. Technically a quarter wavelength resonator will describe it. But

Fig. 5. Voigt (left) is taking a response curve on a recorder at Voigt Patents, Ltd. in the late 1930's. From Wireless World, *July 21, 1933: "Mr. P.G.A.H. Voigt, for some time chief research engineer of Edison-Bell, Ltd., has acquired the stocks of Edison-Bell-Voigt moving coil loudspeakers and electrostatic microphones and has formed a company, Voigt Patents, Ltd., to carry on the manufacture of high grade electroacoustic devices."*

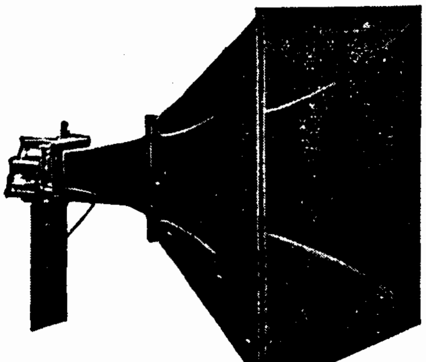


Fig. 4a. Voigt Cinema Horn.[14]

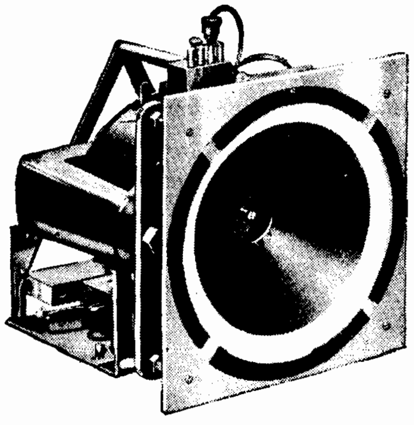


Fig. 4b. Voigt Excited Field Loudspeaker.

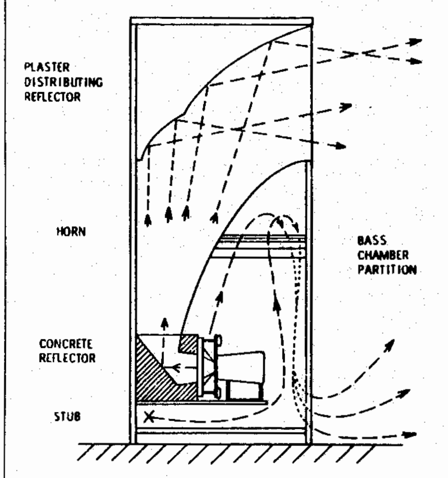


Fig. 6a. Cross-section of the Voigt Domestic Corner Horn. The horn portion had a response down to 100Hz, and the bass chamber used a λ/4 tapered pipe resonant at 50Hz to supply the bass.[15]

Fig. 6b. The corner in a living-room setting. Its base was two feet square, and its height was five feet. Peak production was reached in 1937 when Voigt's staff of nine was producing 12 corner horns a month. A corner horn with driver sold for £32 (unfinished wood) or £49 (luxury cabinet) in 1937.

since it exhausts at floor level in a corner it is feeding into an eighth of a sphere and so is well loaded and thereby highly damped. In addition, the floor and sides of the room act as a substitute flare, so the mouth reflection to be expected from a quarter wavelength pipe resonator is very much reduced. This widens the skirts of the response on each side of the peak, which itself is so much damped that there is no noticeable boominess. (See *Fig. 7* for an explanation of the $\lambda/4$ tapered pipe enclosure.) [*Editor's note:* Voigt was granted British Patent #447,749 for this idea.]

SB: *Did you have any problems with the corner horn response?*

Voigt: I did have trouble with a bump with our domestic corner horns. By themselves they sounded fine, but when compared with the four-foot mouth straight horns that bump could easily be detected. I tried all kinds of things: thin ply for the back boards, saw slots, etc. Every batch of horns for a year or so included some experimental ideas.

In order to help put the problem on a proper footing, I started a year or so before the war developing a tone burst test of a simple kind. I made the burst last 100mS and the space 100mS by switching from a shaft at 5rps synchronized with the mains by gearing off a Baird scanning disc motor. (Baird was an early experimenter with television in England.) With this I could show quite clearly a hangover at about 120Hz. So at least I knew that our corner horns were not aperiodic around the horn limit frequency. By various experiments I could push the hangover frequency about, but not get rid of it. I never completed the total system or solved the problem; some problem we had with Hitler messed up further progress!

After the war I bought a double beam Cossor oscilloscope and was able to show that at the bump frequency the phase up and down the horn flare was substantially the same. This also occurs in a Helmholtz resonator, so my belief that there was some kind of a resonance was reconfirmed. It could could be a cavity resonance. I did start some experiments for absorbing it electrically or mechanically, but was never able to finish them.

SB: *How were your speaker diaphragms made?*

Voigt: I used white paper as used by the draftsman on his drawing board; it was handy and available for the asking. I cut it to shape, bent the cone on the appropriate former, and glued the overlap seam with celluloid cement. Of the techniques developed between the paper makers and the mass-production speaker makers, I have no knowledge. I imagine the dies for forming the paper were not cheap.

Later, when we were making diaphragms for straight horn speakers for talkies, we sprayed the assembled diaphragm with mahogany coloured shellac using a hand-operated gun sold for spraying anti-fly liquids; these were also readily obtainable.

In the early days, the frame around the diaphragms was made of wood, the outside being rectangular (almost square) while the opening (naturally) was round. The flexible surround was at first glued on chamois leather, but I changed that for two reasons: first it was not as elastic as I thought desirable; second, in some cinemas the mice ate it!

As things improved, we made the frames of die cast aluminum, and for surround I used a red material which I think was a form of crepe rubber. It came from the Malay States and was sold in England under the name "Linatex." An aluminum ring clamped the Linatex to the paper diaphragm. The mice showed no interested in that material, but like rubber materials in general it perished with time. It was affected by the atmosphere; in most cinemas, a life of four or five years was quite usual, but cinemas in seaside towns might get only half that. In the domestic corner horns of 1934 onwards a longer life was normal.

During the later '50's, when I lived in Toronto, I was introduced to a flexible plastic material about 0.4mm thick as I recall, made by DuPont under the name Fairprene M5550. It was not quite as elastic as Linatex, but for domestic work that is not as important as in a cinema. When we moved away from Ottawa about 18 years later, it showed no signs of perishing.

SB: *When did you invent the twin cone diaphragm?*

Voigt: I discovered the advantages of using a twin cone to improve the high frequencies in 1933, but it did not improve the high frequencies as much as did the later light coil feature. The twin cone was probably the most "borrowed" of any of my ideas. I licensed my twin cone patent for use in Wharfe-dale's and Goodman's loudspeakers, and they both paid their royalties faithfully.

Because the war spoiled the high quality sound business, I was granted an extension of the patent life. However, patents do not go on for ever, and I had no patents in other countries. What is the position today? Well, not a hifi shop in the world but has a few twin diaphragm loudspeakers in stock; and for every one in stock, how many hundreds are in use? So at least if Rice and Kellogg beat me by a few weeks for the moving coil loudspeaker, I contributed the twin diaphragm. [*Editor's note:* Voigt was granted British Patent #413,758 for the twin diaphragm in 1934.]

SB: *How did you develop your Light Coil Twin (cone) version of the Voigt loudspeaker unit?*

Voigt: While driving to Scotland in the late '30's, my mind returned to the field strength consequences. My main starting point was my 1929 cinema speaker design, which accomplished 16,000 gauss or a bit over in a 2mm. gap of 5mm. axial length. In Teslas, 16,000 gauss (the flux density at which iron shows signs of nearing saturation) is the same as 1600 milli Teslas. If you prefer to be strictly scientific and call it 1.6 Teslas and use that value after explaining to a customer how important it is to have the highest practical field strength, he would probably conclude you were nuts and think you were lying! And the above flux density I had accomplished with 40 watts DC magnetizing.

Now, the only "guidance" on the subject of speech coils I had come across was Olson's book[6] in which he proved mathematically that the optimum mass for the

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FIG. 7

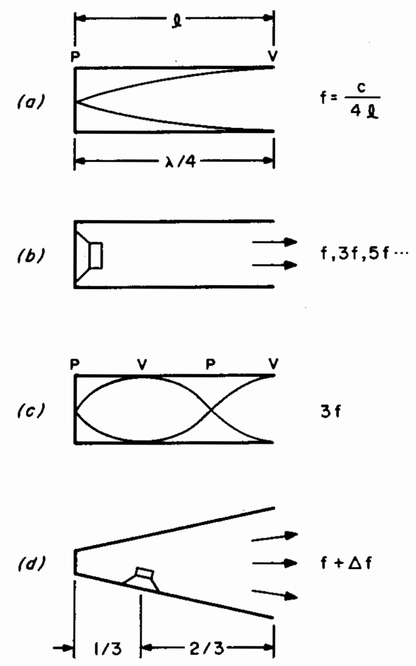

Fig. 7. The Voigt quarter wavelength bass loading enclosure relies on the fact that a $\lambda/4$ closed pipe resonates at the fundamental and odd harmonics. In (a) the fundamental standing wave has a pressure maximum (P) at the closed end and a velocity maximum (V) at the open end. A loudspeaker will be properly loaded if placed at the pressure maximum in (b), but will radiate at the fundamental and all the odd harmonics. At the third harmonic there are two pressure and velocity maximums as shown in (c). Voigt found that if he placed a driver unit one-third of the way down from the closed end (d), the speaker is near a pressure minimum of the third harmonic, reducing the third harmonic excitation. By also tapering the pipe, he was able to broaden the response about the fundamental to give an octave and a half of bass.

P.G.A.H. VOIGT: PART II

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speech coil was that which made it *equal* to the mass of the diaphragm. That may have been correct relative to the assumptions on which his math was based. But I assumed high flux density *was* important. Anyway, my aluminum wire speech coil's mass was far less than that of my twin cone diaphragm (main cone 6″ dia.), so I was already "guilty" of a major deviation from established ideas.

But, if I were to use coil weighing as much as the diaphragm, it would be impossible to squeeze it into a 2mm. gap. To increase the volume of the gap sufficiently for the "established" advice, the electromagnet would have to be increased tremendously. My 1929 design already required 8 lbs. of wire, took 40 watts, and weighed about 30 lbs.

SB: *So what hypotheses did you reach?*

Voigt: If I reduced the speech coil mass still more, it would cut the inertia of the moving parts, improving transient acceleration and high frequency response, though at the loss of average power. Would there really be a loss, and if there were, would it matter? The possibilities either way produced food for cogitation.

SB: *How did you go about redesigning your speaker with these hypotheses?*

Voigt: With a smaller mass of wires, I could reduce the speech coil from six layers to four, and the gap from 2mm. to 1½mm. That reduction would push the flux density up further into the saturation region, in practice by about 2000 gauss (about a 12 percent density gain).

With only four layers instead of six of the same gauge wire, the resistance would go down 66 percent. Now I had two alternatives. Change the output transformer from a secondary for 30Ω to one for 20Ω. Then the voltage would go down by about 12 percent and the current up by about 12 percent. One disadvantage would be changing the transformer; were there others?

With two-thirds the turns, the ampere-turns were down by two-thirds because of the reduced number of turns and up by about 12 percent because of the increased current—i.e. only down to 80 percent considering those two factors alone. But hold it! There is a third factor. With the narrower gap, the flux density will go up; but by how much? Sitting at the wheel of a moving car, I could only guesstimate. Getting into the iron saturation region, how much would the flux density in the gap go up when that gap was reduced from 2mm. to 1½mm.? If the rest of the magnetic circuit was a perfect conductor of magnetism, one could expect the 25 percent gap reduction to give an approximate 33 percent increase in flux density. Suppose, since the iron was going into saturation at the pole tips, which were nowhere near perfect, that one-third of the above increase would be available in practice, then the third factor would provide a 10 percent boost. Eighty percent plus one tenth is 88%!

SB: *So what were the ramifications of these "guesstimates"?*

Voigt: First, that with a coil mass reduction to 66 percent, the force would obviously also go down by 66 percent. This is correct, but not final. If the reduction of mass is obtained by reducing the wire length, charging the input transformer alone helps to counteract the situation and reduces the efficiency drop to 20 percent. On the good side, the reduction of the coil mass has reduced the inertia loss by 33 percent.

I did not mention before that, instead of changing the transformer to suit the reduced resistance load, a change in wire gauge can match the load to the existing transformer. In either case, the mass reduction makes possible a reduction of the gap width, in turn enabling an increase in flux density—by how much is guesswork until you can measure it from a live sample. The limits are easy to imagine but are probably fairy tales.

Suppose you had a magic wand that eliminated the resistance of iron to carrying magnetic flux, then reducing the gap width by a quarter would allow the flux density to increase by a third. We had already a force reduction to 80 percent before considering the beneficial effect of increased flux. The 80 percent relative difference, multiplied by four-thirds, is 107 percent of the original force. In practice such a magic wand does not operate in the saturation region, but it works much better at lower flux densities.

The other imaginary limit is lower. Suppose the iron circuit refuses to carry more flux, then there is no increase, and the above 80 percent figure holds good. Thus, until practical measurements are made with real hardware, reducing the coil mass will produce a force somewhere between 80 and 107 percent of the original. So cogitation showed treble loss could be reduced and transient acceleration improved with no major reduction, and possibly even an increase, in electromagnetic force.

The idea that for good results coil mass should equal diaphragm mass seemed OK to me if you could not "juggle" with the flux density: but I could. Lab measurements showed that reducing the gap to 1½mm. produced a flux density gain of about 2000 gauss—a gain of 1 in 8 over the previous density of slightly over 16,000 gauss.

SB: *With what result?*

Voigt: The result? I deliberately developed a "light coil twin" variation of the Voigt loudspeaker. I knew I was deviating further from the established concept than before, and my title made clear that I was doing it deliberately.

As a practical result, extreme high frequencies were so much better that for AM radio reception we had to put whistle frequency filters into the circuit to cut out the heterodyne beat frequency between adjacent wavelength transmitters. For gramophone use one could cut out the filter, and in the daytime it could be switched in when receiving the B.B.C.

My light coil twin corner horn speaker was submitted for review and received favorable reports, e.g., in *Wireless World*, March 9, 1939. [*Editor's note:* After W.W. II Voigt consolidated many of his arguments for a low mass speech coil and diaphragm in British Patent #667,170 and U.S. Patent #2,615,995.]

SB: *Tell us about your early experiments with stereo.*

Voigt: A few years before the war, I lectured to the Radio Society of Great Britain on sound reproduction and demonstrated with a pair of my corner horns side by side to give 180° distribution. The climax of that lecture was the reproduction of a small orchestra playing live in another room. Initially I connected the two small speakers in parallel, as would be correct for mono reproduction. Then I separated them by about six feet, the distance between the two mikes, and separated their circuits. As far as I know, that was the first demonstration to a British audience of two-channel reproduction. *Wireless World* reported on the meeting in its issue of April 10, 1936.

It is a pity that they call two-channel reproduction "stereo" these days. It is *not* stereo. Real stereo needs not only headphones but mike placing which has in mind that the listener will be wearing headphones.

However, in my stereo demonstrations I was following the lead of Blumlein, who in 1931 invented the stereo record groove (British Patent #394,325). His brilliant idea is now incorporated in every regular stereo record made. I regarded Blumlein as head and shoulders above myself in ability. Had he not been killed during the war in a plane accident while developing a radar system, we would have had many more ideas from him.

SB: *How did your association with Lowther begin?*

Voigt: I first met the young O. P. Lowther at RadiOlympia in 1934. It was his ambition to market the best possible radiogramophone, which naturally needed the best possible speaker. This meeting developed into a very friendly alliance with the Lowther Mfg. Co. Their excellent tuners and amplifiers, together with Voigt speakers, made up the Lowther-Voigt Radiogram, which set a very high standard of performance?

SB: *Describe the research developments of the late '30's.*

Voigt: In those days I had set a tone burst test system and was experimenting with permanent magnets. However, I could not obtain magnets which provided the flux density obtainable with my excited field units. I had hoped a unit being made in time for the 1939 annual RadiOlympia exhibition would do the trick. It was so late in coming that they had to deliver it direct to the address where we and Lowther had rented space near the Olympia building. When we compared it to one of our excited field units, it sounded poor, and we removed it from view. When I measured the flux density it was not up to standard in spite of the large dimension of the magnetic overcoat.

On Sunday, a few days after the exhibition opened, Prime Minister Chamberlain announced that Hitler's forces had invaded Poland and Britain was at war with Germany. That altered everything. On Monday everything was being dismantled. I could not resume my tone burst tests as the noise might be mistaken for some enemy action. Our sales collapsed.

SB: *What did you do during World War II?*

Voigt: With the help of my wife, who did the drafting and bookkeeping chores, we kept Voigt Patents alive doing maintenance work on our cinema horns. This work was deemed necessary for keeping up Home Front morale. The Admiralty did give us some research money, which surprised us because of my German parents—they could be quite sticky about such matters.

SB: *Tell us about your postwar research efforts.*

Voigt: In 1939, when Hitler walked into Poland, Britain had sterner tasks on hand and speaker research stopped in its tracks. By the time the war was in its last stages, newer magnetic materials, known variously at Ticonal, Alcomax, and Alnico V, had proved their worth and were able to provide a magnetomotive force far exceeding that obtainable with 40-50 watts of electrical excitation. When research could be resumed, it was with these newer materials in mind.

This time I concentrated on producing a PM unit with the magnetic material in the center. As a matter of policy, I retained the old stylus as far as possible. I thought it might eventually be practical to convert existing excited-field speakers to PM, thus enabling Voigt speaker owners to bring their speakers up to date at minimum expense.

Our policy on diaphragms had been similar, and when the twin cone came out in 1933 they were mounted so as to make them interchangeable with earlier single cones. When we introduced the light coil twin in 1938 that too was interchangeable. As it required a gap of 1½mm., we made liners which could be fitted to existing magnets. With these the flux density went up to the 18,000-19,000 gauss region?

SB: *What was the relationship between your and Lowther's PM loudspeaker research and developments?*

Voigt: In the postwar period Mr. Chave, Mr. Lowther's former chief technician who now owned the firm, shared my opinion that the excited-field speaker would be regarded as obsolete and therefore we needed a PM version. He pushed on with experiments on a version using the magnetic material externally, while I carried on with my experiments using an internal magnet block. At my suggestion we worked independently and did not compare notes till completion.

The outcome of his work was the Lowther PM series (British Patent #618,802 and #628,432); the outcome of mine was reviewed in *Wireless World*, March, 1949. I subsequently improved the design still further, but it is no longer in production as my company became dormant some years after I emigrated to Canada. (See *Fig. 8*.)

The diaphragms used on the early Lowther PM speakers were supplied by my company, so the speakers were in more ways than one a true Lowther-Voigt combination and were sold as such. The diaphragms used by Lowther's even now differ but little from the genuine Voigt diaphragms of the '30's and '40's. The reason is simple.

When my health started giving trouble in 1946-47, I realized I could no longer supervise the manufacture of handmade diaphragms. I would have to subcontract this work and we would continue only the final test and inspection. I lent all the special tools and jigs needed to the subcontracting firm, and taught them all the special techniques involved. That subcontracting firm was the Lowther Manufacturing Co.; and so when I am credited with being responsible for the PM-2, this is partly correct. But Mr. Chave is responsible for the transition from the Voigt-excited field to the Lowther PM. His work has merit, and it would not be proper for me to accept all of the credit.[3] [*Editor's note:* Part of the confusion between Lowther and Voigt was inadvertently started by George Augspurger's article on horn loudspeakers[7] in which he gave Voigt credit for the Lowther PM speaker. See also the letter by Chave[8] with a different opinion on the subject.]

SB: *What went wrong with your health in 1946?*

Voigt: Briefly, in the later '40's after the war, I began to experience sensations of pressure in my left chest. They were fatigue related and slowed me down. If I walked past the stands slowly at an exhibition, no one noticed. But at a restaurant I could not follow the head waiter to my table in a normal fashion, and it was extremely noticeable.

I consulted a series of medical doctors who applied the standard tests. They could find no reason for my trouble and assured me there was nothing physically wrong with me; they eventually tried to convince me that I was imagining it all! Finally I found an osteopath who diagnosed the problem as a malformation of the spine. A spinal brace was made for me which initially produced daily improvement.

SB: *Why did you decide to move to Canada in 1950?*

Voigt: The war had reduced my firm to a

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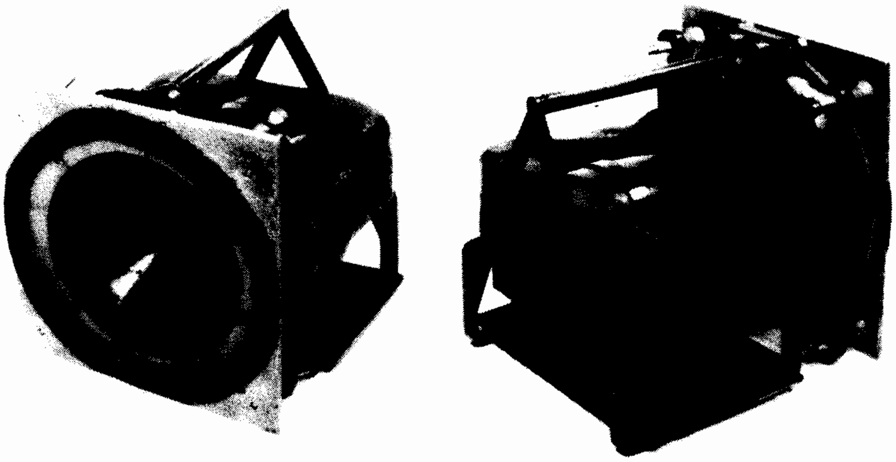

Fig. 8. Light coil twin diaphragm Voigt PM loudspeaker of 1949. The permanent magnet consisted of a large center block of Ticonal with the magnetic return paths supplied by the two large side limbs. The unit weighed about 30 lbs. and cost £37.[16]

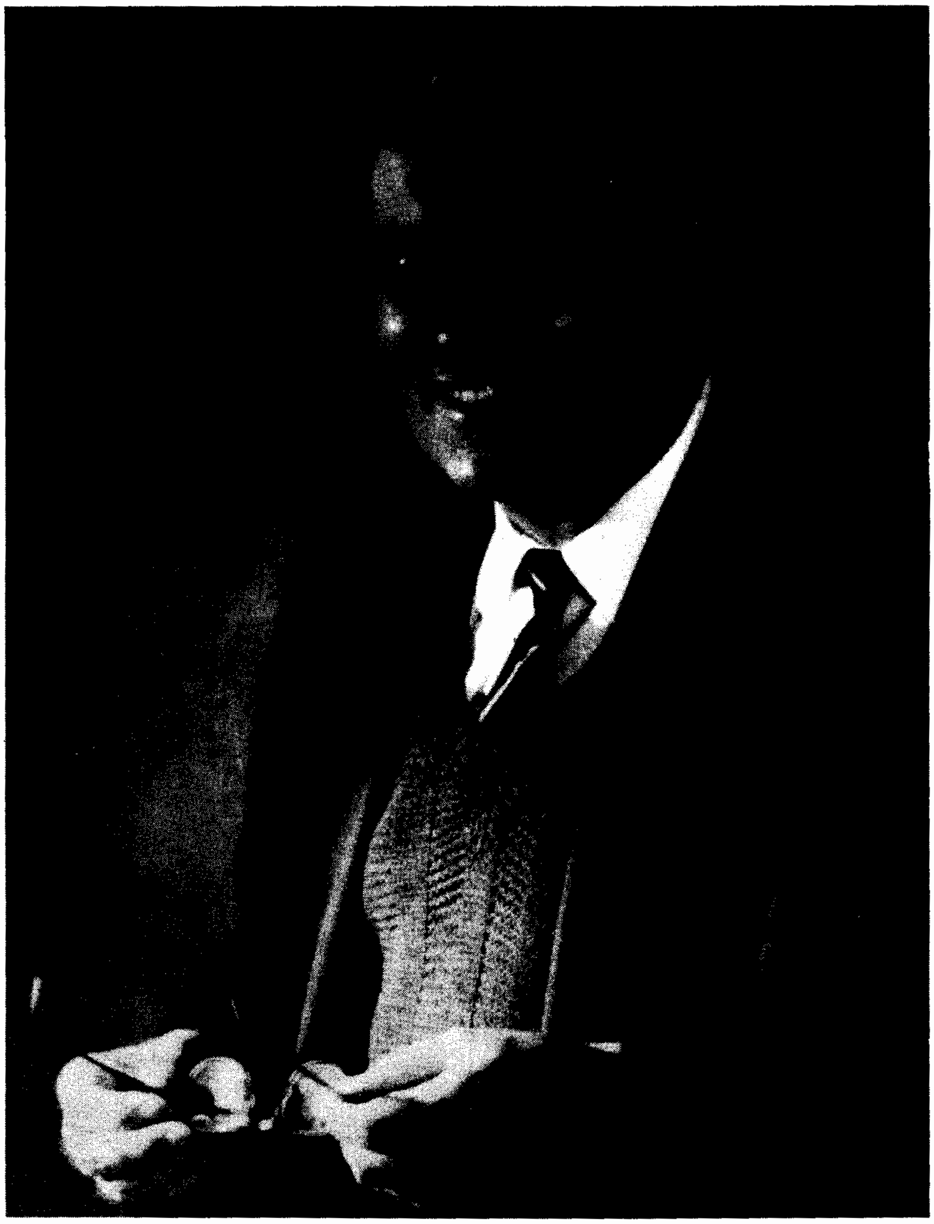

Fig. 9. Paul Voigt, taken about 1970 in Canada.

P.G.A.H. VOIGT: PART II

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skeleton basis. I could see no chance of recovery unless I could build up sufficient export trade, since British purchase tax and rationing of materials tended to reduce our British sales till they were of no consequence. In April, 1950, my wife and I crossed the Atlantic, leaving Voigt Patents, Ltd., running on a skeleton basis in London, England. Our purpose was to build up export sales of my corner horn loudspeaker on this continent specifically, to make sure that I did not have all my eggs in one basket.

My wife had spent a year or so in Toronto somewhere around 1926, so for her it was not a blind shot and she had friends there. I had one helpful audio contact there, and another in New York. From a general point of view, Toronto is within 600 miles of one-third of the population of this continent, and from a personal point of view I felt it would be more satisfying to operate from a part of the British dominions than from the United States. Not only had they come in late for both world wars, but British radio journals at the time had not overlooked inventor Armstrong's suicide because of legal patent troubles.

SB: *What happened to the Canadian venture?*

Voigt: Default by a company I thought I could trust upset the financial situation, and an almost total failure of communications ensured my Canadian venture's doom. The company ran on its own momentum into the mid 1950's, but without substantial export trade it would not and did not survive.

I have two important things to be thankful for. Had the Canadian venture succeeded, without doubt I would have overtaxed my strength and long ago become the late Mr. Voigt. Instead, I am now 79 and in better shape than when I left England in 1950.

SB: *What was your last development in loudspeaker design?*

Voigt: The week before we sailed in April, 1950, I applied for something for ensuring that the spacing between the inner and outer poles of the PM speaker magnet would automatically be accurate upon assembly.

SB: *What did you do after the failure of Voigt Patents, Ltd.?*

Voigt: I had various activities such as teaching electronics, consulting, etc. At one time I worked in the laboratory of a firm which made office dictation machines that recorded on tape. This gave me the opportunity to gain first-hand experience in tape recording research—hardly hifi, but instructive all the same. I was very surprised at the distortion figures for slow tape speeds.

Unsuspected tape distortion may well explain why so many records do not satisfy the ear when heard over really first-class equipment. The highs are there, and the lows, and the mid-range, but they leave you dissatisfied. The sound of live music contains a satisfying richness which many records lack.

In my opinion, freedom from distortion is even more important than a wide frequency range. I regard a distortion-free system with a range of 40-10,000Hz as better than one which distorts appreciably, even though its range may be two octaves wider and run from 20-20,000Hz. The target, of course, is full range without any distortion?

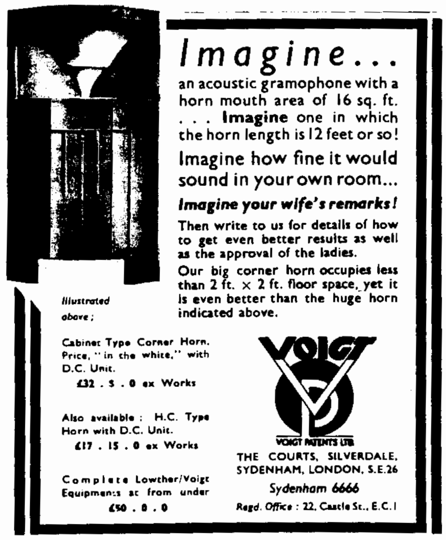
During periods of rest, and in between jobs, I started to think about the basic nature of gravity, electricity, etc. which were more than enough to keep me out of mischief![10]

In 1960 I was employed by the Canadian Federal Government in radio regulations (anti-interference section). I found very satisfactory the time I spent in the lab, developing test techniques, apparatus for direction finding, etc. This gave me a better understanding of the relationship between electricty and magnetism and the electromagnetic wave, and so on. In 1970 I retired to a country dwelling in Brighton, Ont. with more time to concentrate on the riddles of the fundamentals of nature.

SB: *Where did you meet Paul Klipsch?*

Voigt: At the 1974 Audio Engineering Society meeting in New York, someone asked whether I or Paul Klipsch was first with corner horns. As I was about to answer, the fellow with the mobile mike went over to someone in the audience section and I was saved from replying, for he told the audience that when he was applying for his patent my work was among that brought up against him. Klipsch himself was speaking.

From there I picked up and filled in details. I told the audience that, after reading his first horn paper, I had sent him



a copy of our literature as I thought it would interest him. However, not knowing his address, I sent it to the organization that published his paper. It was never acknowledged, so I did not know if it had ever reached him, or whether he was very busy or simply impolite. He replied that he had no recollection of receiving it, and so a question which had been in my mind for 30 years had been favorably answered. After the meeting he invited us all to lunch and later to his hotel room to see some of his slides—very interesting. So Klipsch is no longer just a name to me.

[*Editor's note:* Klipsch told me he later tried to find out the exact claims held against him, but the details could not be found in his patent papers. At that 1974 AES meeting Paul Voigt was made an honorary member of the Audio Engineering Society "in recognition of his pioneering achievements in the pickup, recording, and reproduction of sound."[11]]

SB: *Can you review the progress of your*

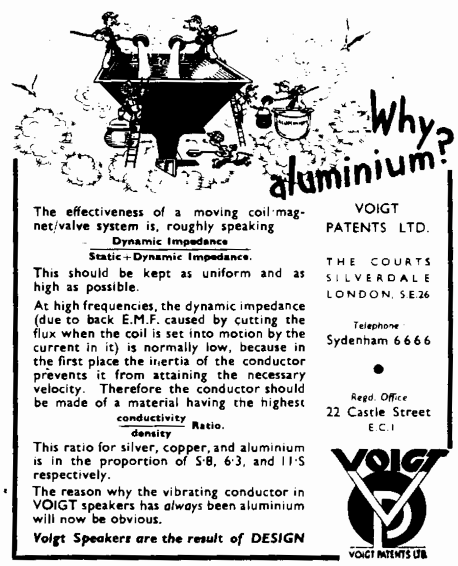


Fig. 10. A sampling of advertisements for Voigt Patents, Ltd. Voigt wrote all his own ads and never repeated an ad once it had been published. These ads appeared in The Gramophone *in 1937.*

Voigt speakers from the '30's to the '50's?

Voigt: The 1929 cinema speaker had a flux density of 16,000 gauss across a 2mm. gap with 40-50 watts field excitation. The axial length of the gap was about 5mm. In the later '30's, for our light coil twin diaphragm as used in the domestic corner horn, the gap was reduced to 1½mm., which improved the flux to 18,000-19,000 gauss with the same excitation. At the end of the '40's, with a new speech coil design I could go down to a 1mm. gap. By then we had a permanent magnet, but I had to design a 20,000 ampere-turn magnetizer for it. By 1950 the flux density was 22,000-23,000 gauss in prototypes. It never went into production because of the failure of Voigt Patents, Ltd.

SB: *Have you any advice for testing loudspeakers?*

Voigt: The final test should be your ear test. Some people are concerned with organ pedal tones, some with clarity or edginess of cymbals and triangles; but the real test of a speaker system is male speech. If that sounds boxy, boomy, or unnatural in any way, something is very wrong somewhere. It may be in the studio or mike; but if the same kind of unnaturalness persists on all program material the trouble is usually in the speaker or enclosure![12]

And one thing: occasionally go to a live concert in a hall with no public address system gear, just to keep your ideas in line![13]

"That wise old owl P.G.A.H. Voigt,
One all-important point has toigt:
When speakers sound like ailing mouses,
What they need's a good dose of Gausses."

Anon, *Hi Fi News*, 1964

> Errata to Part 1: Figure 2a should read moving armature loudspeaker instead of "moving coil loudspeaker."

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