The Remarkable Dr. Hendrik van der Bijl

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Invited Paper

The article contains biographical information about this South African Physicist who while continuing his studies in Germany investigated photoelectric emission using an apparatus with a photocathode, an anode, and a grid similar to de Forest's Audion. He established the behavior of this three-element system and subsequently extended the analysis to apply to the thermionic triode at the Western Electric Laboratories in New York. He used this knowledge to design many of the first tubes used in radio and telephony; he invented the grid modulation system for radiotelephony and wrote the first textbook on the vacuum tube in 1920. Soon afterwards he returned to South Africa as Scientific Advisor to the Government and created a countrywide electricity supply network, a world class steel corporation, and numerous other important industrial enterprises.

Keywords— *Amplifiers, cathode-ray tubes, electron tubes, history, modulation, photoelectricity, repeaters.*

I. Introduction

When viewed against the incredible advances made in electronics in the second half of this century, it is easy to undervalue the contribution, in the first half, of the thermionic vacuum tube. The science of electronics depends primarily on amplifiers, whether the application is analog or digital. Power gain is what made the miracles happen, and the vacuum tube provided the first effective means of achieving this.

Before 1907 the distinction between light-current and heavy-current electrical engineering was really only one of magnitude. Telegraphs and telephones were based on electromechanical devices, and radio transmission was achieved using electrical equipment modified to generate and respond to high frequencies.

The need for an amplifier was increasingly felt in both the telephone and radio fields. De Forest seemed to have found a possible solution, and in 1913 the Western Electric Company decided that it should be investigated thoroughly. Dr. Hendrik van der Bijl was hired to work with the team investigating the de Forest Audion and found the following job awaiting him [2].

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Fig. 1. Church Street in Pretoria, South Africa, just after van der Bijl was born. President Kruger lived quite close to this point. Photograph by H. F. Gros.

> When I joined the Western Electric Company at that time I was shown an Audion and was told that it was capable of detecting radio waves and capable of amplifying feeble telephone currents, but that it was not known how or why, and that it was to be my task to find that out.

Van der Bijl's 1918 Classic Paper, reprinted from the Proceedings of the Institute of Radio Engineers, brings together his experience in designing and using thermionic vacuum tubes as amplifiers. His mathematical analysis of the triode stood the test of time and formed the basis for amplifier design until the transistor usurped its position in the 1950's.

II. Van der Bijl's Formative Years

Hendrik Johannes van der Bijl (pronounced *fun der bail*) was born in Pretoria, South Africa, on November 23, 1887. He was the fifth child in a family which eventually grew to eight. Their South African origins dated back to 1668 when Gerrit van der Bijl arrived at the Cape from Holland to serve the Dutch East India Company.

During van der Bijl's childhood, Pretoria was the capital of President Kruger's South African Republic, an area better known as the Transvaal (see Figs. 1 and 2). The

Fig. 2. Church Square, Pretoria. The ox wagons brought the faithful from outlying districts to Nachtmal (Communion). Photograph by H. F. Gros.

conservative Dutch-speaking community was deeply religious but rarely intellectual. His father was developing a prosperous farm produce business and the boy grew up in an atmosphere conducive to broader thinking. Gold was already being mined in the northern part of the territory and the Witwatersrand Goldfields had only just been discovered, but the weak national economy was still largely dependent on agriculture.

The Anglo–Boer War started when van der Bijl was 12 years old, and he experienced much of the bitterness and unrest spawned by this unfortunate event. The family remained in Pretoria until the city was occupied by the British in mid 1900. At that stage his parents decided to move to the Cape, where van der Bijl was able to complete his schooling while well removed from the ravages of war.

At school he was not noted for brilliance, but his teachers remembered his studious disposition and the fact that he read more widely than his fellows. After matriculating at Franschhoek High School he spent three years at Victoria College (now the University of Stellenbosch). Here he received the B.A. degree, winning a college prize for physics and the van der Horst Prize for the most deserving student of mathematics and physical science in the college. This may sound impressive, but the competition could not have been severe as he was only the third student to graduate in Physics from this institution.

In 1908 in South Africa there was little that van der Bijl could do with his degree as he was not interested in teaching and there was no industry looking for his services. Evidently he had formed a high opinion of the scientific work being done in Germany and decided that he would like to continue his studies there. He seemed quite unconcerned by the fact that he knew no German, and he soon acquired sufficient proficiency to write technical papers and lecture in that language.

III. Studying in Germany

He spent a semester at Halle University studying philosophy and inorganic chemistry. His preference for science crystallized at that stage and he moved to Leipzig to work under Professors Wiener, des Coudres, and Jaffé, who had impressed him by their fine work. By March 1912 he had successfully completed a Doctorate on the behavior of ions produced by a strong radium source in selected liquid dielectrics [21]. He must have particularly impressed Wiener because he recommended van der Bijl for a Physics Assistant post at the Royal School of Technology, Dresden. Such posts were generally reserved for German students and required the incumbent to remain in the position for at least two years. He was not willing to commit himself to such an extended period and managed to persuade the authorities to take him on for only one year (or longer if he so desired).

The Head of the Department of Physics at Dresden was Prof. Hallwachs, who had done much of the early research on the photoelectric effect. In 1900 the German physicist Planck had proposed the Quantum Theory to explain the mechanism of absorption and emission of electromagnetic waves by resonators of atomic or subatomic dimensions. In 1905 Einstein applied the Quantum Theory to the photoelectric effect and proposed a linear relationship between the wavelength of the light and the maximum velocity of electrons emitted from the irradiated metal. Quantum mechanics had not yet been widely accepted by the scientific community, and this relationship was seen as a means to test its validity. Several attempts to do this had already been made but all they had achieved was to convince the doubters that the Quantum Theory should be abandoned. Hallwachs brought this problem to van der Bijl's attention and suggested that he look into it.

IV. Work on the Photoelectric Effect

At that time the apparatus usually chosen to determine the maximum velocity of emission consisted of an irradiated photocathode and an anode with a metallic grid interposed between them (see Fig. 3). Both the anode A and the grid N had a central hole to allow the light to reach the photocathode P. Electrons emitted by P were drawn to the anode A through the grid N. The negative potential on the grid was then raised to the point where the anode current was cut off, and this was taken to be the maximum velocity (measured in volts) of electrons emitted by the photocathode. It was generally accepted that the plane containing the grid would provide a uniform equipotential surface which could be varied by changing the voltage C [1], [2].

To satisfy Einstein's equation, the maximum electron velocity should be in the region of a few volts, but most workers had found grid voltages more than ten times greater. Van der Bijl suspected that the field due to the relatively high anode potential penetrated the grid and produced a "stray field" between the grid and the cathode. He designed a special version of the photoelectric tube (see Fig. 3) which allowed the distance between the grid and the anode to be preset to convenient values. The distance between the cathode and the grid could be changed while the tube was under vacuum to facilitate measurement of the

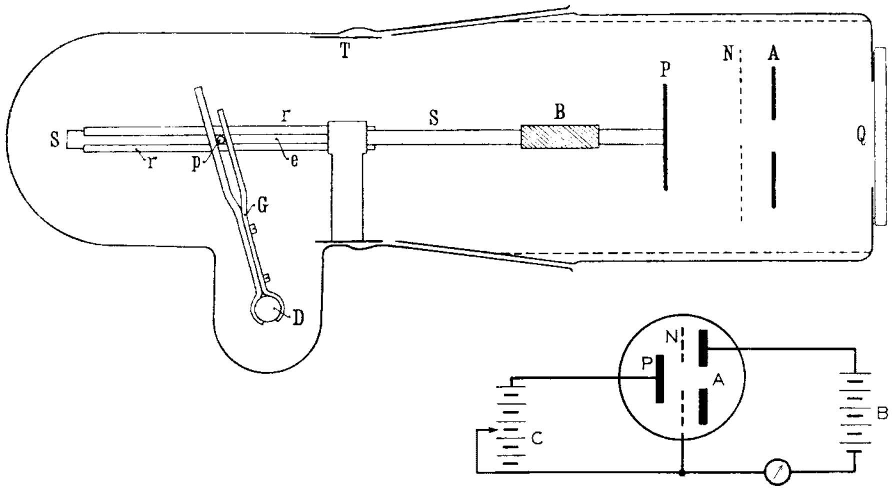

Fig. 3. The evacuated glass vessel used by van der Bijl to determine the maximum velocity of electrons emitted by zinc irradiated by ultraviolet light [1], [2].

contact potential between the grid and the cathode. With this apparatus he was able to find the combinations of grid and anode voltage which would just reduce the anode current to zero for various distances between the anode and the grid. Fig. 4 shows a typical plot for two different grid-anode spacings from [1]. The relationship is clearly linear, and by extrapolating it to the vertical axis the inferred grid voltage corresponding to zero anode potential was the same for both spacings (about 4 V). Under these inferred conditions the influence of the anode-grid field on the grid-cathode field being removed, the true retarding potential depended only on the cathode-grid potential. In this way he eventually reached voltages which came close to the value satisfying Einstein's photoelectric equation. He concluded that the field between the anode and the grid penetrated the grid and that its effect on the cathode-grid field was proportional to the anode voltage.

Equation (3) from [1] expressed this relationship as follows:

$$v = \frac{k}{d}V + \eta \quad (\text{for } I_{\text{anode}} = 0)$$

where

- v the grid-cathode voltage;
- V the grid-anode voltage;
- d the distance between the anode and the grid;
- η the intercept with the vertical axis is the corrected voltage acting on electrons emitted by the cathode;
- k a factor relating to the grid geometry and the electrode spacing.

The above equation relates the extent to which the electric field between the anode and the grid strayed through the grid and influenced the cathode-grid field. This was later used as the basis for the behavior of the thermionic vacuum tube and was the source of the well-known amplification factor μ (the reciprocal of k).

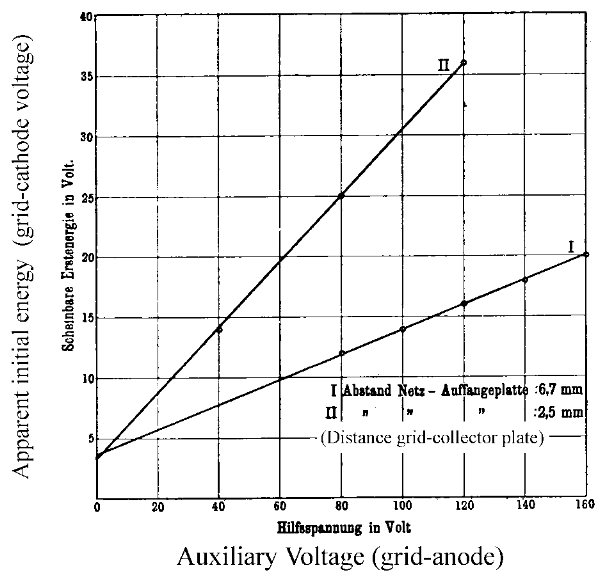

Fig. 4. Combinations of anode and grid voltage which just reduced the anode current to zero in van der Bijl's photoelectric apparatus [1].

In [1] he also showed curves relating anode current to grid-cathode voltage for several anode-grid voltages (see Fig. 5) these are recognizably similar to those for thermionic triodes.

V. Professor Millikan

One of the leading specialists in electron theory was Millikan, a Professor of Physics at Chicago University. Millikan had also been trying to satisfy the Einstein photoelectric equation using an apparatus similar to that used by van der Bijl. His unsatisfactory results had turned him into "an avowed opponent of light quanta and was trying to prove Einstein wrong," [3]. Soon after van der Bijl had completed his experimental work, Millikan came to

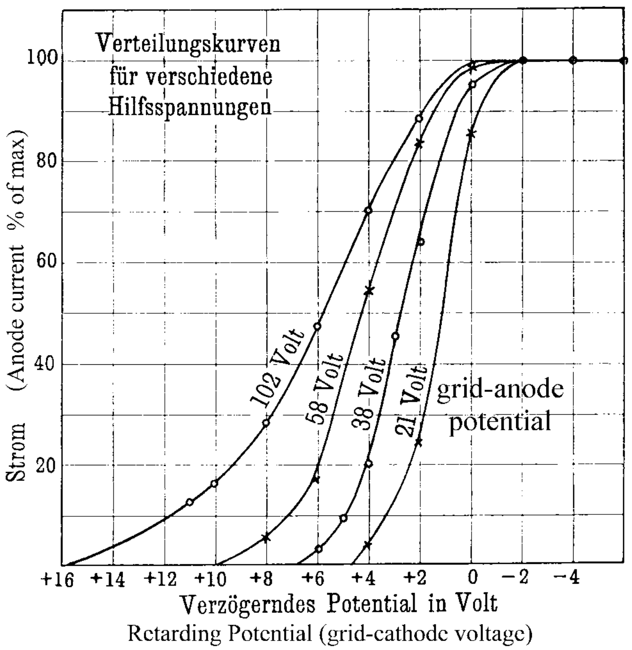

Fig. 5. Relationship between the anode current and the grid/cathode voltage in van der Bijl's photoelectric apparatus. Similar curves were commonly displayed for thermionic vacuum tubes [1].

Germany to read a paper relating to his discovery of very high-emission velocities. Subsequently he paid a visit to Dresden and van der Bijl (possibly because he spoke English) was given the job of showing him around. During the course of the visit van der Bijl noted the following [4]:

> . . .we compared notes and found that his extraordinarily high velocities were due to the same cause, viz.: the stray field. It was, of course, a very great disappointment to him but this disappointment was outweighed by the joy which naturally came to him as a true scientist when he found that my experiments confirmed the deductions from the Electron Theory. We remained great friends ever after.

Millikan thereafter changed from being an opponent of Einstein's photoelectric theory to become the man who eventually proved Einstein's equation to be correct. In 1916 Millikan published the results of his subsequent experimental work [5] which fully justified Einstein's photoelectric theory. This paper gives a more rigorous confirmation of Einstein's theory than the work done by van der Bijl, and as the apparatus used did not require a grid he did not make use of van der Bijl's stray field relationship. Millikan does not acknowledge van der Bijl's paper and van der Bijl nowhere refers to Millikan's subsequent work, but it seems clear that, at the very least, van der Bijl's work must have moved Millikan to return to the problem and finally find the solution.

Millikan was at that time Technical Adviser to the American Telephone and Telegraph Company and was aware that their subsidiary, the Western Electric Company, was negotiating for the rights to use de Forest's Audion as a telephone amplifier. He could see that van der Bijl's investigation was not only relevant to the Quantum Theory but also to the thermionic vacuum tube.

In the last paragraph of [1] van der Bijl mentions loose ends which he felt should be dealt with but adds the following comment: "The author could not at this stage continue with the tests since he was leaving Germany." With World War I only 17 months away it is probable that he already sensed the need to leave the country. On March 20, 1913 he wrote to Millikan asking for help in finding a suitable research position at one of the American universities. Millikan showed van der Bijl's letter to Colpitts, a senior research engineer at Western Electric (best known for his oscillator circuit) with the suggestion that they should offer van der Bijl a position in their laboratories. Colpitts wrote to Dresden on May 28 suggesting that van der Bijl should visit them in New York to see whether he might like to join their industrial research team. By the time the letter reached Germany, van der Bijl had already left for Chicago. In July, Jewett, Assistant Chief Engineer of Western Electric, met van der Bijl in Chicago and offered him employment in their Research Department at a starting salary of $36 a week. Van der Bijl presumably spent some time vacationing before joining the Western Electric Laboratories in September 1913.

VI. Western Electric

By 1912, Arnold of Western Electric had developed a successful telephone amplifier using a mercury-arc tube. De Forest offered Western Electric the Audion (for the second time) at the end of October 1912 and Arnold saw that, despite a lack of understanding of how it functioned, this device had possible advantages as a telephone amplifier (see Fig. 6).

An agreement must have been struck with de Forest almost immediately because Arnold was asked to organize a study of the device to see what was needed to remove its shortcomings (de Forest was eventually paid $50 000 for the use of the Audion in telephony but not until July 1913). Arnold and his team started by removing the series capacitor in the grid circuit which was effective in a radio detector but which blocked the operation of an audio amplifier at higher input voltages. De Forest believed that the Audion needed vestiges of gas to operate efficiently, which was true when it was used as a detector. As an amplifier Arnold could see that this caused erratic behavior and limited the maximum anode voltage and hence the output power. By November they had already improved the vacuum sufficiently to operate the tube at 80 V. In April 1913 they received a Gaede Molecular Pump which was used to further improve the vacuum so that they could safely raise the anode to 200 V (de Forest's tube was limited to about 20 V). Glass arbors were introduced to support the electrodes firmly. The filaments of de Forest's Audions were heated to incandescence which limited their life to between 35 and 100 hours [6]. Arnold introduced Wehnelt oxide-coated filaments which could

Fig. 6. A large anode de Forest Audion made especially for Western Electric for telephone repeater tests where higher power was required. The filament of this burnt out tube was added artificially. Tube in SAIEE collection; photo by the author.

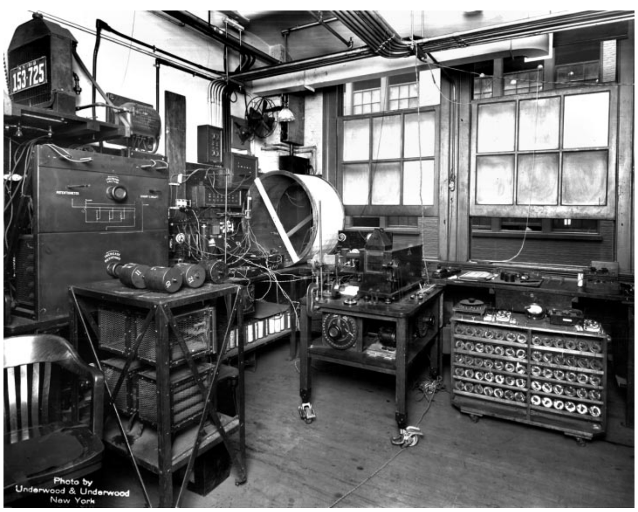

Fig. 7. Electronic laboratory at Western Electric, New York, c. 1915. The large inductor on the workbench was probably destined for the Arlington transmitter. Note trolleys containing a 90-V battery of dry cells and a mechanical oscillograph. Photograph from Vaal Teknorama.

produce adequate emission at much lower temperatures with less power and a longer life. Finally, larger anodes and grids were placed on both sides of the filament to increase the power handling of the tube. By the fall of 1913 these improvements were incorporated into prototype tubes which were successfully used in a tests between New York and Washington.

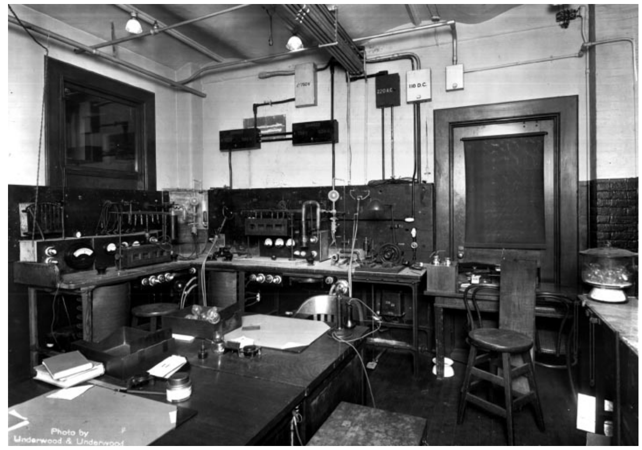

Fig. 8. Vacuum tube laboratory at Western Electric, New York. Photograph from Vaal Teknorama.

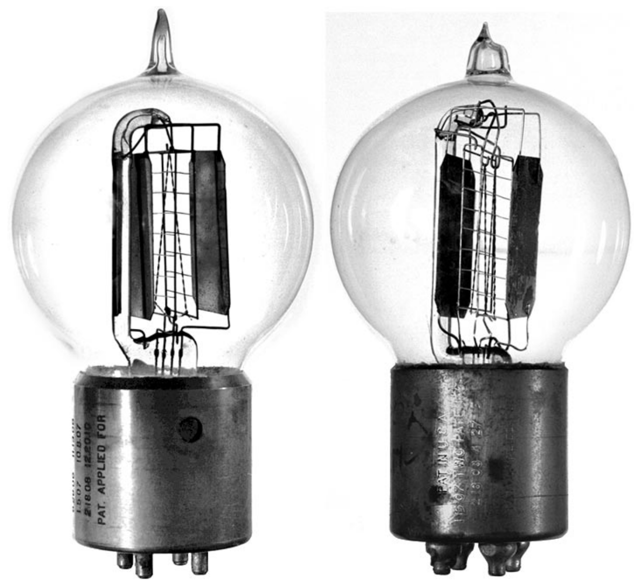

Fig. 9. The tube on the left hand side is the first designed by van der Bijl (type M or 101A). On the right is an improved version (type L or 101B with double inverted V filament). These were the tubes used on the transcontinental telephone line in 1914. The M stood for mounted (in these prototypes the base was made from machined brass) and the L stood for line. Tubes in SAIEE collection; photo by the author.

Van der Bijl joined the company at about this time and recognized that the thermionic triode was very similar to the photoelectric tube he had used in Dresden. He developed the stray field relationship which he had discovered in Germany and the factor k (appearing in (3) of his photoelectric paper [1]), became the amplification factor μ. Together with the anode resistance R and transconductance S, these remained the basic amplifier parameters until the transistor took over after World War II. With his team he investigated the effects of electrode spacing and grid proportions on tube performance making it possible to design tubes for particular purposes (see Figs. 7, 8, and 10 and [7, pp. 227–236]). His Classic Paper, reprinted in this PROCEEDINGS, sets out his analysis of vacuum tube behavior in detail.

Fig. 10. Van der Bijl (standing on the left) photographed with, presumably, three of his colleagues from Western Electric in New York in December 1914. We think that Arnold (having removed his glasses) may be seated on the right. The author would be grateful to anyone who can identify the three associates. Photograph from Vaal Teknorama.

His first tube was the type M, or 101A (see Fig. 9) designed for use as a telephone line amplifier and the first Western Electric tube to be provided with a base mating with a mounting socket to facilitate replacement.

Late in 1909, during talks with the management of the Panama-Pacific Exposition due to open in San Francisco, CA, in 1914, Vail and Carty, two senior executives of the company, had virtually promised that they would have a telephone working between New York and San Francisco in time for the opening of the exhibition. On their return to New York it is said that Vail told his engineers, “We’ve promised it; now you find a way to do it,” [8].

Three lines were constructed so that comparative tests could be made between the three types of amplifiers then available. The first, designed by Shreeve, was a mechanical amplifier using an electromagnetic receiver coupled directly to a carbon microphone which provided adequate gain but produced distortion which limited the number which could be cascaded. The second was Arnold’s mercury-vapor-discharge tube, which was suitable for telephone line use but required skilled maintainance. The third line was fitted with amplifiers using van der Bijl’s type 101A tube.

The vacuum tube emerged as a clear winner and van der Bijl always treasured the certificate confirming his membership in the Society of Planners and Builders of the First Transcontinental Telephone Line which was issued to each of the main participants [9].

By then, management was convinced that the vacuum tube held great promise, and van der Bijl was encouraged to develop and expand his knowledge of the triode. An immediate benefit came from a study of filament performance which revealed that the life could be improved considerably by increasing the electron-emitting area. The 101A tube had an inverted Vee filament drawing 1.45 A at 4 V. He replaced this with a double inverted Vee form which required 1.3 A at 5 V and increased the life from 400 h to 4500 h (see Fig. 9 and [6]).

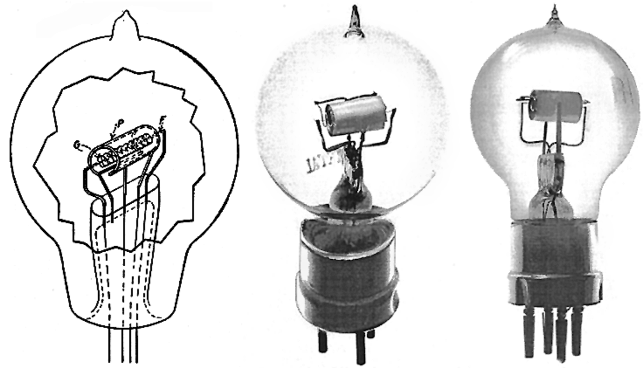

Fig. 11. On the left is a sketch of “a tube of simple construction” designed and produced by van der Bijl in September 1914. He claims that this was the origin of the French TM tube, an example of which is shown in the center. The British R valve shown on the right was based on the TM. Many millions of these tubes were made during and after World War I. Tubes in SAIEE collection; photo by the author.

In September 1914, just after the start of World War I, van der Bijl designed a robust tube with coaxial cylindrical electrodes suitable for radio work which could be produced economically for military purposes. Fig. 11 includes the drawing of this tube which was prepared for U.S. Patent Application 1 738 269 (Dec. 1918) and which also appears in [7, p. 244]. Presumably, Western Electric ignored this design because it did not measure up to the needs of the telephone industry and failed to see the potential of the emerging military market. In three separate statements spread over almost 30 years, van der Bijl claims that this design forms the basis of the historical French *Telegraphe Militaire* (TM) tube (see Fig. 11). Several millions of these were made in France and the U.K. (where it was known as the R valve). The author has tried, unsucessfully thus far, to find independent confirmation of this claim. As this is an important step in the history of the vacuum tube it justifies further investigation and it is hoped that this exposure will stimulate other researchers to contribute to the debate. The author will be glad to send copies of his notes and references to anyone wishing to participate [10].

In 1915, after successfully linking the country coast-to-coast by telephone, Western Electric turned its attention to transoceanic communication by experimenting with radio telephony. Speech had already been transmitted by radio but no method suitable for commercial use had thus far emerged. A team of engineers was assembled at Western Electric to explore the use of the vacuum tube for this purpose. Van der Bijl’s main contribution was the grid modulation system which was applied at a low level and amplified by up to 500 power tubes connected in parallel (the special power tubes for the transmitter were not designed by van der Bijl). The equipment was installed at the Navy Signaling station at Arlington, VA, so that it could take advantage of their large and efficient long-wave antennas. It succeeded in reaching Honolulu (7800 km) and Paris (6000 km) in 1915. For a more detailed account of this initiative see [11].

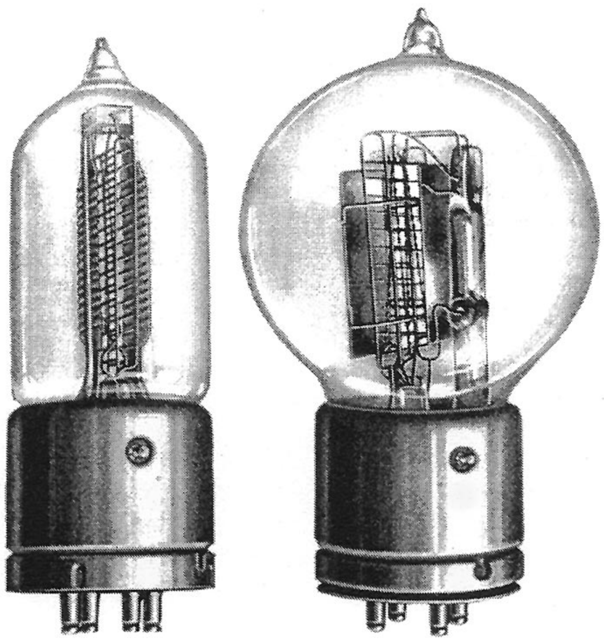

Fig. 12. Van der Bijl designed the VT-1 receiving tube (on the left) and the VT-2 transmitting tube for use in aircraft radio transceivers in 1917. Photographs from [13].

Van der Bijl met Wagner, an American girl and a descendant of the composer, while she was studying music in Germany. They must have met up again in New York as they married in 1915. However, this marriage ended in divorce and his subsequent marriage to Buxton in 1942 produced a son and two daughters.

VII. World War I

By the time America entered the war in April 1917 the Western Electric team was well placed to develop and produce vacuum tubes and advanced telephone and radio equipment for the military. In particular, they were responsible for the SCR-68 radiotelephone transceiver which was widely used for communicating with the early primitive biplanes [12], [13]. The two rugged tubes, VT-1 and VT-2 (see Fig. 12), used in this equipment were designed by van der Bijl [14], and by the end of the war a combined total of over a half million of these tubes had been made by Western Electric.

Toward the end of the war, van der Bijl was asked to develop a tube drawing the least possible filament power for use in battery-operated trench sets. The filament of the resulting VT-3 tube (see Fig. 13) drew 0.2 A from a 2 V cell (0.4 W), which was about a tenth of the power required by previous tubes. The war ended before it could be put to military use, but van der Bijl continued with the development and produced the remarkably small tube known as the "peanut tube" using a simplified construction for which he was granted U.S. Patent 1 566 293 (see Fig. 13). Western Electric made very few of these tubes but the design was licensed to several other manufacturers including Westinghouse (WD 11 [15]) and three in the United Kingdom where it was known as the Wecovalve.

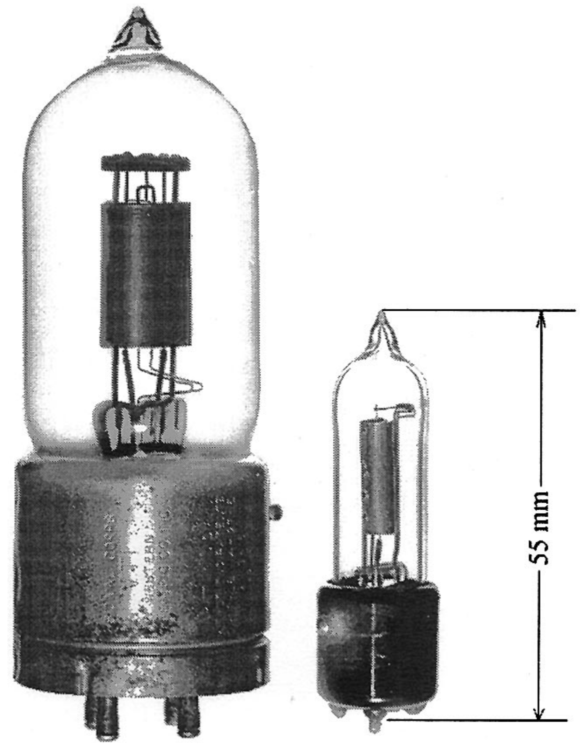

Fig. 13. The tube on the right is a prototype VT-3 (mounted in a VT-1 enclosure) which had greatly reduced filament power consumption and was intended for use in portable trench radios. The war ended before this tube could be put into production but van der Bijl developed it into the type N (215) or "peanut tube" shown on the right. Tubes in SAIEE collection; photo by the author.

The reduced filament power was greatly appreciated by the domestic radio market at a time when filaments were usually supplied by accumulators or dry cells.

VIII. Other Contributions

Van der Bijl worked on several other projects while he was in New York, including a speech inversion system which was eventually used to maintain secrecy on radio telephone circuits in the early 1930's and a frequency division telegraph multiplexing system (U.S. Patent 1 502 889). He did some early investigations into facsimile transmission and introduced the use of photoelectric cells to register light-intensity variations in preference to the intended use of selenium cells.

There was a pressing need for a convenient cathode ray oscillograph to view high-speed electrical phenomena. The Braun tube had served this purpose quite well but it was heavy and cumbersome due to its high voltage power supply. Johnson of Western Electric had reduced the accelerating voltage considerably by replacing the cold cathode with an oxide-coated heated filament, but he ran into difficulties with focusing the electron beam. Van der Bijl suggested introducing a small amount of gas which became ionized by the electron beam and provided a surrounding field which reduced the scatter ([12] and U.S. Patent 1 565 873). Gas-focused cathode ray tubes were widely used in the 1920's before the problem was solved using electron optics (see Fig. 14).

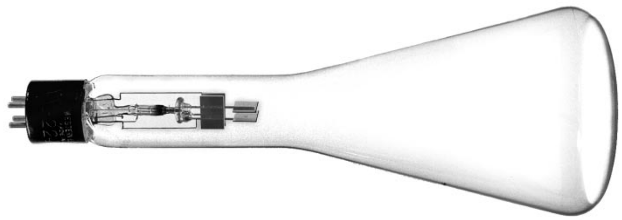

Fig. 14. Van der Bijl suggested gas focusing these early cathode ray tubes intended for use in oscilloscopes. Tube in SAIEE collection, photo by the author.

Van der Bijl gave expert witness in numerous patent disputes involving Western Electric. Notable among these was the Arnold versus Langmuir Interference 40 380, where testimony was also given by Richardson and Millikan [14].

U.S. Patent Interference 45 928 against Chubb and his rectifier patent 1 657 223 asserted that van der Bijl had investigated smoothed half-wave and voltage doubler rectifier circuits as well as a DC to DC convertor using vacuum tubes as early as May 1914 [16].

In 1920, McGraw-Hill published his book *The Thermionic Vacuum Tube and Its Applications*. This summarized his work between 1913–1919 and became the standard textbook on the subject until well into the 1930's with a total sale of about 10 000 copies. In 1924 McGraw-Hill suggested that the text should be brought up to date, but by that time van der Bijl had entered a new phase in his career and could not consider doing it himself. King, then Editor of the *Bell System Technical Journal*, was asked whether he would be willing to undertake the revision; he seems to have made a number of suggestions on how this should be done. Unfortunately, van der Bijl was not happy with the approach and the suggestions were never implemented. It is remarkable that a book on this rapidly developing subject written in 1920 should still have been selling as late as 1940.

Gen. Smuts, who served on the British War Cabinet from 1915–1918, was impressed by the scientific advice available to British ministers. He became Prime Minister of the Union of South Africa in 1919 and decided that his cabinet needed a Scientific Advisor. Having heard of van der Bijl's achievements in America he decided that Hendrik was the man for the job. Van der Bijl was placed in a difficult position: on the one hand he was deeply entrenched at Western Electric doing work that he loved; on the other hand he had a deep roots in the country of his birth, which had enormous unrealized industrial potential and where he believed he could make an important contribution.

In August 1920 van der Bijl's colleagues at Western Electric bade him farewell with a whale of a party at which he was serenaded with a seven verse song to the tune of "The Gondoliers." The words were set out, together with the signatures of 68 of his colleagues, on a large sheet of paper which van der Bijl had framed and which is now in the archives of the South African Institute of Electrical Engineers. The second verse reads as follows.

> His fame is great, his brow is high,
> Through working out equations;
> 'til they're in a highly exhausted state,
> with horrible integrations,
> His equal you will seldom find,
> In anything whatever;
> Of that there is no manner of doubt, etc. etc.

On page 262 of the book published by Bell Telephone Laboratories [12] to mark the centenary of the invention of the telephone, tribute is paid to the work of van der Bijl as follows.

> He was largely responsible for analyzing tube performance in terms of simple parameters and establishing techniques for designing circuits with performance predictable from these parameters.

IX. Return to South Africa

In 1920 van der Bijl returned to South Africa to take up the position of Scientific and Industrial Adviser to the department of Mines and Industries. He reported directly to Smuts, which gave him quite exceptional powers. Not surprisingly, the established civil servants did not take kindly to his position, and although he concluded several projects he was not at all happy with the situation and seriously considered returning to America.

A proposal to link the countries of the British Empire with a series of long-wave wireless telegraphy transmitters had been shelved at the beginning of World War I. Subsequently, a chain of radio stations, spaced 2000 miles apart, was being implemented when the Marconi Company lobbied for the system to be dropped in favor of their proposed direct links using short waves. By 1922 Australia had decided to back the new solution, but South Africa remained undecided. Van der Bijl was given the job of assessing the merits of the alternatives and favored the short-wave solution, which was eventually adapted by all the participating countries [17].

Clearly van der Bijl was still thinking about vacuum tubes and, stimulated perhaps by the forthcoming high-power short-wave radio links, he considered ways and means of making high-power tubes for radio transmitters. He believed that the solution lay in making the anode also serve as the tube enclosure, thus placing it in direct contact with the cooling medium. The problem lay with sealing the junction of the metal container and the glass structure supporting the remainder of the tube. Van der Bijl provided a platinum collar welded to the metal envelope at one end and fused to the glass at the other. It is possible to fuse glass to platinum without fear of fracture at higher temperatures because platinum has practically the same coefficient of expansion as glass. Unknown to van der Bijl, Houskeeper had been working along similar lines at Western Electric. Houskeeper's seal relied on thinning the metal container where it was to be fused to the glass so that the internal stresses due to expansion were insufficient to cause cracking. Van der Bijl was granted a South African patent [18] for his solution and applied for U.K. [19] and

U.S. patents [20]. He had already negotiated royalties with the Marconi company to manufacture such tubes when they read, in the first issue of the *Bell System Technical Journal*, that Western Electric were already producing such tubes.

Smuts persuaded van der Bijl to form a national electricity supply undertaking and van der Bijl was made Chairman of the newly established Electricity Supply Commission in March 1923. This was a nonprofit public utility company which strengthened under his leadership and is today the main source of electrical power in South Africa. This seems to have settled his thinking because from then on, although the difficulties surrounding his enterprises did not diminsh, his dedication to his vision of an industrialized South Africa became quite unshakeable.

Van der Bijl saw that the two pillars on which industry would be built were adequate and economical supplies of electric power and steel. A small steel-making business was already functioning but it was undercapitalized. At the time South African business was focused on the gold mining industry and there were few entrepreneurs with sufficient confidence in the future to invest in a steel business which was quite content to import its requirements. Van der Bijl persuaded the State to create a second public utility company to embark on this business on an adequate scale. Opposition was loud and persistent, but in 1925 he headed a new company known as the Iron and Steel Corporation (Iscor) which again prospered under his leadership and continues successfully to this day.

Van der Bijl saw the need to encourage smaller private enterprises, and in 1940 he persuaded the state to create the Industrial Development Corporation (IDC) to provide capital for promising enterprises. He was Chairman during its first three years of operation, and the IDC is still functioning today.

X. WORLD WAR II

Once World War II started, South Africans began to realize just how dependent they were on imported goods, and with communications severely limited something had to be done urgently. Van der Bijl was made Director General of War Supplies and mobilized the country's limited industrial resources in a remarkably short time. He arranged production facilities for guns, bombs, armored cars, precision instruments, military explosives and ammunition. Other existing industries such as weaving, clothing, leatherware, and canned foods were given a boost and developed rapidly so that the country could become independent of imported supplies.

As a Senior Civil Servant van der Bijl was remunerated quite adequately but could never accumulate the wealth a businessman of his stature would expect in private enterprise. He was more concerned about the quality of the products of a venture than with its potential profits and was convinced that the best vehicle for running a major undertaking was as a nonprofit making business with the state as sole shareholder. The Director General of War Supplies was expected to join the Cabinet but when Smuts invited van der Bijl to do so he declined, justifying his action with the following comment [9, p. 155].

> At present I have no enemies that I know of, but if I join the Cabinet I shall immediately have 40 per cent of the population against me and I shall have to waste my time making conciliatory and tactful speeches.

Fig. 15. Hendrik van der Bijl in later life. Photograph from Vaal Teknorama.

After the war he directed expansion of the steel industry into a new industrial area known as Vanderbijl Park (near Vereeniging). A new ideal town was planned to house the workers complete with all facilities such as hospitals, schools, parks, etc., and in typical van der Bijl fashion this was achieved as perfectly as humanly possible. Here he floated the Vanderbijl Engineering Corporation (Vecor) to provide for the country's heavy engineering needs. In association with U.S. interests he started the South African Marine Corporation to provide for shipping between South Africa and the United States.

In 1943 he was elected Foreign Associate of the National Academy of Sciences of the United States and Fellow of the Royal Society in 1944. In 1945 he was Vice-President of the Institute of Radio Engineers (see Fig. 15).

His unsophisticated backwoods beginning did not prevent this remarkable man from leaving his mark on the twentieth century. The IEEE is highlighting the impact he made on the world of electronics by reprinting his 1918 Classic Paper, "Theory and Operating Characteristics of the Thermionic Amplifier." Unfortunately, his even greater contribution to the development of South Africa has been largely forgotten by his countrymen.

We shall never know what van der Bijl might have achieved in his later years, because his full life came to a premature end when he died of cancer at the age of 60 in 1948.

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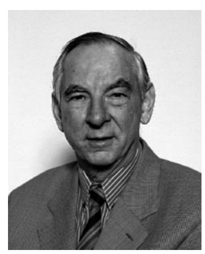

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It was at the University of Witwatersrand that he was introduced to the work of Dr. van der Bijl by Prof. G. R. Bozzoli. He did an industrial apprenticeship with the Automatic Telephone and Electric Company, Liverpool, U.K. (spawned by the Automatic Electric Company in the United States). At the R&D laboratories of the South African mining industry in Johannesburg he developed two-way radio equipment for use underground in gold and coal mines as well as work on other mining problems. He then joined a company manufacturing electronic railway signaling equipment. In retirement he has been able to indulge in several interests, including archaeology and the history of science and technology. His specializations are the work of Dr. H. J. van der Bijl and the development of the electrical power industry in South Africa. Together with a team of enthusiasts he is trying to start a Science Center in Johannesburg.