Discussion of "A History of Some Foundations of Modern Radio-Electronic Technology"

Critique by Lloyd Espenschied*

In tracing their own inventing over the years, Hammond and Purington[1] recall interestingly the evolution of our modern art from the time of spark wireless telegraphy as of about 1910. But they give the impression that their inventing played a more foundational role than was the case. With the possible exception of Fritz Lowenstein's realization of the amplifier out of de Forest's grid audion detector, which appears to have been conceived before he became associated with Hammond, it may be said that the roots of our modern technology trace back generally to sources other than the Hammond Laboratory. Actually, Hammond's work was conducted in secret, as the authors aver, while speculative patents, filed prolifically, were long held in the Patent Office. Meanwhile the advance rolled on, with its literature accumulating, generally oblivious of the Hammond group. Hence claims made in the paper to "firsts" and to the establishment of "principles" are in need of amendment, as discussed below. The writer regrets having to turn critic, for he welcomed the rendering of the Hammond story. As it is, the paper will contribute more to technical history by calling for additional evidence. We follow the sections of the paper beginning with Section II.

The Radiodynamic Torpedo (Section II)

Hammond is best known for his long pursuit of the problem of directing torpedoes by radio control. As still earlier pioneers in this field, mention is made in the paper of a pair of British inventors and of N. Tesla. But singularly omitted from mention is the one who received from the U. S. Patent Office the underlying claims, one of which reads:

> The combination with a source of electrical waves or disturbances of a moving vessel or vehicle and mechanism thereon for steering or operating the same, and controlling apparatus adapted to be actuated by the influence of the said waves or disturbances at a distance from the source, as set forth.

This is Patent No. 660,155, one of a pair, means and method patents, granted to Lieutenant (later Admiral) Bradley A. Fiske, October 23, 1900. Fiske had filed only a few months after Tesla in 1898 and was able to swear back of Tesla and obtain the primary claims. In 1912 Hammond wrote from Washington, D. C., a letter[2] inquiring about this patent, saying "I am very much interested in Patent No. 660,155 . . . ." and going on to observe: "This is the first record of any kind which completely covers the art of wireless control of mechanisms." Thus, one wonders why Fiske is not cited as a pioneer, or *the* pioneer, in the present paper. In the summer of 1915 Hammond was selling to a Congress worried by the European war then raging, his system of wireless control of torpedoes. Fiske became concerned lest his patents be infringed and issued a public statement explaining how he came to make the invention, and observing that, "Mr. John Hays Hammond, Jr. has done splendid work based on my original patent."[3] In his autobiography of 1919 Fiske wrote, " . . . I do not know of Mr. Hammond ever giving me credit for having suggested the plan originally, or of his disclaiming the credit given him for it in many accounts of his achievements."[4]

Of course it was quite impossible for any of the early inventors to get very far on this problem, so crude was early radio; and even after the revolutionary high-vacuum tube came along, to reach an underwater vessel with control signals was most difficult. Two World Wars have now occurred with no military use of the radio-controlled torpedo; it is just as well, except for the futile expenditure of technical effort and public money.

Among the "principles" claimed to have been developed in the 1910–1914 period is that of the automatic stabilization of the course of a torpedo by means of the gyro.[5] Yet one reads in the *Encyclopaedia Britannica* of 1910–1911, eleventh edition, under the article on "Torpedo," of gyrocontrol trials in 1896 which "demonstrated the feasibility of accurately and automatically steering a torpedo in a direct line by this means," and of the Whitehead firm having "produced the apparatus which is fitted to every torpedo made."

Under the subheading "Automatic Course Stabilization" it is said, " . . . in 1912, the Sperry Gyroscope Company and the U. S. Navy were developing a precise and reliable motor-driven gyrocompass with remote repeaters." This development is understood to have been undertaken by Sperry alone, the Navy adopting the system upon its appearance in 1911. The paper continues: "The Hammond Laboratory engineered the modification of one of these devices so that the repeater controlled not a compass indicator, but the operation of a steering engine." This modification was rather obvious since the idea of steering a ship automatically from a magnetic compass was old. This connecting of a Sperry gyro to a steering gear instead of to a compass indicator is referred to as the "automatic pilot principle," as if the automatic pilot originated with Hammond.

This section of the paper, under the previously mentioned subheading "Automatic Course Stabilization," is made more confusing by the inclusion in it of a reference to three Hammond patents,[6] as if these patents cover course stabilization and the automatic pilot. They do not; they apply only to the application thereto of radio control. In fact, the arrangement shown for combining gyro and steering engine is unserviceably crude—the control is intermittent rather than continuous, through declutching, and there is no means for restoring the rudder to normal after a turn, *i.e.*, repeat back, so necessary for an operable automatic pilot. Thus, the three patents added nothing to automatic course stabilization *per se* and their inclusion at this point in the text is misleading.

The man who pioneered and produced the automatic pilot was Elmer A. Sperry. His early progress is described in a comprehensive paper of 1913. "Perhaps the most interesting of all the apparatus which we have developed is the aeroplane stabilizer, . . . " the section on this subject begins. It was applied to a Curtiss Hydroplane, and is pictured in Figs. 28 and 29.[7]

Under the subheading "Security of Radio Control,"[8] Tesla is credited with having "proposed a security system based upon the coincidental transmission on two channels: a forerunner of the 'and' principle of modern computers." But ahead of Tesla, apparently, were the two British inventors, Wilson and Evans, mentioned earlier in the paper. Their U. S. Patent No. 663,400 of 1898–1900, shows coincidental transmission over two channels. Two short-wave Hertzian dipoles disposed mutually perpendicular with a similar pair for receiving, provide two channels by polarization. The receiving control electromagnet is made dependent for its operation upon the receipt of both channels, whereby it appears Tesla was limited to two different frequencies.

A so-called Hammond system which uses in a conjoint manner the familiar marking and spacing waves of the Poulsen arc transmitter is described. Later in the paper this is made the basis of claims to FM. But de Forest, then of the Federal Telegraph Company, who installed Hammond's arc equipment in 1913, already had devised what he called " . . . a diplex system of telegraphy, using a high-speed chopper." It "automatically changed the wavelength of the transmitter from *A* to *B* a great number of times per second, so that both the *A* and *B* operators could dispatch their messages. . . . "[9] Hence the Hammond claim to " . . . the first example of security systems using both time and frequency diversity" appears to have been an adaptation to a slow "security" operation of de Forest's diplex.

* Received by the IRE, December 2, 1957.

[1] Proc. IRE, vol. 45, pp. 1191–1208; September, 1957.

[2] Letter of January 11, 1912, written to the Western Electric Co., 463 West St., New York, N. Y.

[3] *The New York Times*, p. 11, col. 3; July 24, 1915.

[4] B. A. Fiske, "From Midshipman to Rear-Admiral," The Century Co., New York, N. Y., p. 232; 1919.

[5] Footnote 1, p. 1192.

[6] Footnote 1, p. 1192, reference 7.

[7] E. A. Sperry, "Engineering applications of the gyroscope," *J. Franklin Inst.*, vol. 175, pp. 447–482; May, 1913.

[8] Footnote 1, p. 1193.

[9] L. de Forest, "Father of Radio; The Autobiography of Lee de Forest," Wilcox and Follett Co., Chicago, Ill., p. 277; 1950.

Toward the end of Section II of the paper,[10] there is quoted a claim from a Hammond patent of 1932–1936[11] which is said to be "the statement of the Proximity Fuse principle." This is erroneous, for the claim is for a *torpedo*, meaning in water, from which the energy radiated must be compressional or sound waves, the only kind disclosed in the patent, whereas the proximity fuse employs radio waves.

The Triode Tube (Section III)

The technological revolution that has resulted from the electron tube requires that reports of its onset be rendered correctly. The report given in the paper is from the standpoint of the Hammond group, and while this is a welcome contribution, it is by nature limited and one-sided, and contains some errors. Hence, additional evidence is offered as follows.

The second paragraph quotes our old friend Robert Marriott as having written that de Forest's Audion "was used to some extent as early as 1906 . . . ". The quotation is correct, but the assumption that it referred to the triode rather than the diode, as of 1906, is in error. It was the two-element tube that was publicly christened that year with the name Audion in de Forest's AIEE paper of October 20, 1906, devoted to the diode and entitled simply, "The Audion." Incidentally, Pupin amusingly said of the name: "It is a mongrel. It is a Latin word with a Greek ending!" And he expressed dissatisfaction with de Forest's inability to explain its *modus operandi*.[12] In his recent autobiography, de Forest refers to his detector tube as "a carbon filament surrounded by a platinum plate,"[13] which he used in receiving at 42 Broadway, New York, in 1906.

The grid triode appears to have been invented toward the very end of that year or the beginning of 1907. It was filed upon January 29, 1907 and issued as a patent February 18, 1907, No. 879,532, entitled "Improvement in Oscillation Detectors." (There was no time lost in those days!) Just ahead of it de Forest had devised another form of triode, one in which the control electrode was a second plate located on the side of the filament opposite to the anode. He sought to make of it a telephone amplifier; but being unable to obtain amplification, contented himself with filing a speculative patent application October 25, 1906. It was issued January 15, 1907, as No. 841,387, entitled "Device for Amplifying Feeble Electrical Currents." Interestingly enough, the patent drawing shows, connected in series with the input control electrode, a condenser such as became familiar in the grid audion detector. But whereas in the grid tube it enhanced the detector action, it could only do harm in the amplifier, causing it to block. This probably was one reason for the failure of the two-plate amplifier, the other being the lesser electrostatic control of the filament-anode electron path. So, it fell to the grid form of tube to lead the way.

The earliest public disclosure known to have been made of the grid audion detector was in a lecture de Forest gave on March 14, 1907, on "The Wireless Transmission of Intelligence," before the Brooklyn Institute of Arts and Sciences. It was about that time that the grid audion began to come into some use, "but apparently in very small numbers," as Marriott said. Among those small users, to the writer's knowledge, were a few amateurs who learned where the bulbs could be procured, managed to save up the required $5, and then suffered the filament burn-out soon to follow! The writer, with two other amateurs, Austen M. Curtis and Francis A. Hart, had attended de Forest's Brooklyn lecture and there made the acquaintance of "Doc" and his young assistant John V. L. Hogan. The grid audion detector continued for some years solely as a detector without getting very far, as the authors of the paper indicate, for it was relatively expensive and only moderately more sensitive than the simple crystal-contact detector.

Hammond and Purington are to be congratulated for having at long last pulled aside the curtain of secrecy and revealed Fritz Lowenstein's contribution in making de Forest's grid audion detector into an amplifier and also an oscillator. But they do not tell the whole story and give the impression of Hammond's role having been more than it was. It was not actually "as a consultant of the Hammond Laboratory," that "Lowenstein on May 11, 1911, undertook in New York the development of the three element 'ion controller' . . . ". The date is that of a letter-contract[14] which defined the Hammond-Lowenstein relations, addressed by Hammond to Lowenstein and signed by both, which runs as follows:

> May 11, 1911.
>
> Frederick Lowenstein, Esq.,
> 115 Nassau Street,
> New York City.
>
> Dear Mr. Lowenstein:
>
> I am writing you a letter to confirm the points taken up in our conversation this morning at the Hotel Belmont, with Mr. John Hays Hammond and Mr. George Clark. These points, as I recollect, are as follows:
>
> You are to work and develop two separate inventions—one, my own automatic wireless selective system, and the other, your controller.
>
> On account of the development of my wireless selective system, I agree to advance to you the sum of $1,000.00 for your personal supervision, advice and services in the designing and construction of my invention. . . .
>
> In the second proposition, to develop your controller, I shall advance you the sum of $1,000.00 for the purpose of constructing such apparatus as may be necessary for experimentation, with a view to perfecting your controller. . . .

(The term "controller," or "ion controller," was Fritz's alias for the name "Audion" which de Forest had bestowed upon Fleming's tube upon adding to it the "B" battery.) The rest of the agreement gives Hammond an option to take a 50 per cent interest in the controller invention (which is understood not to have been exercised).

From the above it is evident that Lowenstein was a consultant to Hammond for the latter's selective radio system for torpedo control, but not in respect to his own ion controller. Hammond's relation to Lowenstein in respect to the ion controller was that of financial backer, or business partner. This is borne out by the fact that in applying for a patent Lowenstein used his own patent attorney; and when he later sold the patent to the American Telephone and Telegraph Company the payment, of the famous $150,000, was to him. Fritz had tried the grid audion as an amplifier before becoming associated with Hammond. This is indicated in his letter to Hammond of September 19, 1911, quoted in part in the paper, wherein Lowenstein speaks of his "efforts on reproducing the telephone tests of last winter . . . ,"[15] the winter of 1909–1910. What these tests were, fortunately, has been told by Fritz himself in another document, in an affidavit submitted to the Patent Examiner in the course of prosecuting his patent application—that which became the famous negative grid, or "C" battery, Patent No. 1,231,764 of 1912–1917. The affidavit, sworn to on September 8, 1915, is to be found in the Patent Office record of that patent. It describes how interest was first aroused by an experience in 1906 wherein Lowenstein observed the sensitivity to electrostatic influence of a Cooper-Hewitt mercury arc rectifier. It then goes on to say:

> In the winter of 1909–1910 I did some work as a consulting expert to the President of the Radio Telephone Company of Newark, N. J., and in their shop and at that time I constructed and assembled an operative telephone system of which the receiving end was arranged substantially as shown in the drawings of my above application, except that the grid 18 was simply connected to one side of the filament 16, *i.e.*, at the same potential as the filament.

Accompanying the affidavit were Exhibits A, B, and C. The latter, a reproduction of the patent drawing, shows a grid Audion provided with audio input and output transformers connected as an amplifier in the receiving leg of a standard telephone subscriber instrument.

The affidavit continues:

> In 1911 I did further work on the invention in the way of perfecting details thereof.

(*i.e.*, when backed by Hammond). The affidavit then reveals how Fritz came to substitute for the grid condenser of the audion detector the negative "C" battery which made of it a class A amplifier, which negative grid condition proved to be the invention of the patent.

> The apparatus employed in the 1911 tests were constructed with the aid of Benjamin T. Miessner (now at Purdue, Indiana), and George H. Scherff, of New York City.
>
> In a talk in 1911 with Louis Engelhorn at the Chicago end of the line, and Harris Hammond and myself at the New York end, we employed a condenser in the grid circuit and found that the talk over the line was poor, the current through the controller tending to choke or stop. I found that this could be remedied readily by touching the grid binding post repeatedly to discharge the grid and open up the talk. This gave me the idea of connecting the grid to a point ultranegative in potential relative to the filament. Such a connection was actually made in the latter part of 1911 and was found to be a very substantial improvement.

These, then, were the steps by which Lowenstein converted de Forest's grid audion detector to the magic amplifier it became:

[10] Footnote 1, p. 1197.
[11] Footnote 1, p. 1197, reference 21.
[12] L. de Forest, "The audion," *Proc. AIEE*, vol. 25, pp. 719–747; October 20, 1906. Discussion, pp. 863–873.
[13] de Forest, *op. cit.*, p. 210.
[14] This letter-contract has kindly been made available to the writer by the authors. It was part of a report by E. S. Purington, "Early History of Selective Receiving Systems with Special Reference to . . . Cases of RCA vs Splitdorf Co., and RCA vs George H. Walker Co.," p. 22; February 19, 1938.
[15] Footnote 1, p. 1198.

1) Initial interest in the possibility of some form of vacuum tube amplifier, aroused through contact with Peter Cooper-Hewitt's mercury arc rectifier tube (a form of which Hewitt himself was developing as an amplifier).
2) Familiarity with the Audion grid detector, gained while working as a consultant for de Forest's old Radio Telephone Company, soon defaulted, 1909–1910, which led Fritz to try to make of the audion an audio-frequency amplifier. He seems to have had some success, but evidently kept it to himself at the time; his obligation to the Company is not known.
3) Renewal of the audion amplifier tests in the fall of 1911 with Hammond's backing, resulting in amplified reception of long-distance telephone calls and in the attainment of a true Class A amplifier by means of the negative grid discovery.

Therefore, it is seen that Lowenstein was on the trail of the audion amplifier before becoming associated with Hammond and carrying out the "further work on the invention in the way of perfecting the details thereof." Under these circumstances the paper is misleading in implying that he started the development on May 11, 1911 and in the capacity of consultant to the Hammond Laboratory.

The Oscillating Audion

It is well established, as the authors say, that Lowenstein had the audion amplifier working as an oscillator toward the end of 1911, and for both audio and radio frequencies. The strange thing is that it was not followed up, the more so in view of Hammond's high hopes for it as expressed in his letter to Beach Thompson of January 25, 1912, given below. And it is singular that to Hammond, "The exact nature of the ionic devices and the manner of operation are not known." One wonders too that the evidence of Lowenstein's having the audion as an oscillation generator during the winter of 1911–1912 was not presented to the courts in the long de Forest-Armstrong litigation over the oscillating tube. Such evidence would have demonstrated the natural tendency of an amplifier to oscillate and hence how little invention there was in the oscillating audion *per se* once it had become an amplifier. As matters were allowed to go, it fell to others to give to the world the oscillating audion in useful form, most notably, perhaps in terms of early date and application of control of frequency, to Alexander Meissner of Telefunken[16] using a gaseous tube of the von Lieben Triode.

An Important Tip

In view of its probable importance for de Forest, then working at Palo Alto, Calif., for the Federal Telegraph Company, the letter which Hammond wrote the President of that company, and from which the Hammong-Purington paper quotes in part, deserves to appear in full:

January 25, 1911.
(Typist's error, should be 1912)

Beach Thompson, Esq.,
President, Federal Telegraph Co.,
Merchants Exchange Building,
San Francisco, California.

Dear Sir:

I have recently been informed about the wireless work you have been doing on the Pacific Coast, and I am much interested in the results that you have obtained. If you have any descriptive matter I would appreciate your sending it to me.

I have been experimenting with a new form of apparatus designed to produce undamped and high frequency oscillations. Our method is far more reliable and simpler than the Poulsen arc method, or the high frequency alternator system as used by Fessenden and others. We are in process of developing this apparatus, and when it has reached a practical point, I would be very glad to send you more complete information regarding it.

In the experiments we have found that our method is highly suitable for wireless telephony, as there is absolutely no sound produced whatsoever as in the arc or hf alternator. I believe that telegraphy by means of undamped high frequency oscillations is the logical future of this art, for the reasons which you have already discovered and proven: that far better tuning may be obtained where there is no decrement to the wave train, and that there is less absorption of energy in long distance transmission, and also the important fact that low voltages are used at the transmitting station. However, the chief weakness in all systems of this kind is essentially in the means of producing the continuous high frequency oscillations.

I am quite familiar with the art in Europe and during my recent trip to Germany found that most of the companies had abandoned the arc method of oscillation production. It is for this reason that I believe there is quite a future in the development of the work which we are carrying on.

Hoping that you will be kind enough to send me any data which you may be willing to disclose, believe me

Yours very truly,

JHHJr/T

On the same day Hammond wrote to an acquaintance of Thompson, and since this letter, too, is evidence of a stimulative tip given the Pacific Coast people, it is presented:

January 25, 1912

Major F. R. Burnham
Llankershim Building
Los Angeles, California.

Dear Major:

I want to thank you very much for your letter in regard to wireless development in California. It certainly is very interesting to me as the reports I have had of this enterprise have been very meagre. I will herewith write Beach Thompson, informing him that the iron controller which you saw in my experimental laboratory here has recently shown some remarkable results in experiments in which we produced high frequency undamped oscillations with far better results than have ever been obtained by the Poulsen method.

I hope some day that I will be able to introduce a wireless system in Sonora. After the Yaqui has developed enough they will need a station there, and we could furnish a good one.

Very sincerely yours,

JHHJr/T

(The term "iron controller" is a stenographic slip for "ion controller.")

Photo copy of each of the above letters (from Hammond's file carbon copy) were kindly given the present writer some years back by Hammond and Purington. Appreciating the probable bearing of them upon de Forest's making the audion into an amplifier at Palo Alto in the summer of 1912, a copy of the letters was sent to him, with the question of whether they may not account for Beach Thompson having asked him to undertake the further development of his audion. Dr. de Forest's response was: "I do not recall that Beach Thompson ever mentioned his correspondence with Hammond, but very likely that is what induced Thompson to urge me to develop the audion as an amplifier."[17] Whereby we see that Lowenstein, having been indebted to de Forest in the first place for the vital grid tube, repaid his obligation through Hammond's letter, perhaps unwittingly!

Bell System Side of the Picture

An insight into what was happening within the Bell System at the time of the Hammond-Lowenstein approach may be welcome: the American Telephone and Telegraph Company and associated Western Electric Company already had started tackling the telephone repeater problem from the standpoint of a vacuum tube element of some kind. From the University of Chicago laboratory of Prof. Robert A. Millikan a young graduate student, Dr. H. D. Arnold, had been recruited. He started to work at the beginning of 1911 and took up the kind of vacuum tube that seemed likely to carry the load of a telephone repeater, the mercury-arc tube similar to that of Peter Cooper-Hewitt. He had succeeded in getting amplification when our present story opens.

On January 27, 1912, Hammond and Lowenstein took to the office of transmission engineer F. B. Jewett a sealed box and demonstrated it as a prospective telephone repeater. Further contact was made in June, and there were additional telephone conversations, but not until January 12, 1913, while Lowenstein was in Europe, was it fully disclosed what was in the "Black Box."

Meanwhile de Forest himself had succeeded in making his audion into an amplifier on the Pacific Coast, in the summer of 1912, and through John Stone-Stone approached the American Telephone and Telegraph Company. De Forest came east and on October 30 and 31 demonstrated the audion as an audio amplifier to Dr. Jewett and E. H. Colpitts in the laboratory of the Western Electric Company, at 463 West St., New York. He left the device, and the following day, November 1, Colpitts called in Arnold and showed it to him. Arnold later testified frankly as to his impression: " . . . when I went into the room and saw this thing and saw how it worked I was very much astonished and somewhat chagrined because I had overlooked the wonderful possibilities of that third electrode operation, the grid operation in the audion. . . . I knew about the de Forest audion in print, but I was wrong in my impression of what the de Forest audion might do because I had not realized what the grid would do in such a device."[18]

Thereupon Arnold turned from his own mercury arc tube to embrace the audion. As demonstrated by de Forest it was a remarkably sensitive but weak and unreliable amplifier. It would amplify only at low speech levels, about 30 db down; at normal levels it would block and produce noise, for the audion still had in it the grid condenser of its radio detecting days! This trouble was soon overcome and Arnold then addressed himself to the improvement of the tube itself. He had recognized from the beginning

[16] A. Meissner, "The development of tube transmitters by the Telefunken Company," PROC. IRE, vol. 10, pp. 3–23; February, 1922.

[17] Letter to Dr. L. de Forest to L. Espenschied, September 15, 1953.

[18] Arnold-Langmuir high-vacuum tube litigation. Testimony of 1926 in the District Court of the U. S., District of Delaware, No. 589 and 598. In Equity. General Electric Co., Plaintiff, vs The de Forest Radio Co., Defendant. Vol. I of six volumes, pp. 554–556.

that the "blue haze" was due to gas and sought better evacuation. The best of the tubes de Forest had left with Western were repeatedly pushed to the highest plate voltages they would stand to clean up the gas in them. Other tubes were obtained from the manufacturer, McCandless; the electrical characteristics were measured; and by the end of the year Arnold and his assistants had a fair mastery of the newcomer. There was ordered from Germany the latest type of vacuum pump (Gaede, molecular); and upon its arrival in April, 1913, Arnold started making his own tubes of high vacuum and greatly improved design.

Thus, the Western Electric Company engineers were already familiar with the audion when in January, 1913 Lowenstein's "black box" was opened to them. They had expected to find something new, and were disappointed when there appeared only "the ordinary audion" as they reported. The negative grid was noted and Colpitts in his report mentioned that the question of its potential was to be studied and the company should be free to employ any polarization. This point must have seemed minor to his boss Jewett, for he lost sight of it. An examination of the patent papers submitted by Hammond revealed that the three claims stood rejected by the Patent Examiner on two de Forest patents. The work of the Austro-German von Lieben group was then coming to attention, on which the Lowenstein claims were soon to be rejected by the Patent Office. Altogether, the American Telephone and Telegraph Company's patent attorney Lockwood reported, "I do not see that the Lowenstein people really have anything to sell," and since they were unable to demonstrate to the contrary, the case was dropped. But Lowenstein's patent attorney, M. C. Massie, was persistent and resourceful. A few years later he managed to get allowed claims on the negative grid. Imagine the surprise of the telephone patent people when the patent was issued in 1917 with claims that read on the grid polarization that the engineers had found to be necessary and that was then in use! So, the patent was bought, quietly, for the very considerable sum of $150,000. Massie told the writer afterward that the company originally could have had the patent for $20,000 and he had finally boosted the price to $200,000, to come down to the amount agreed upon!

Thereby hangs a supplementary tale too good not to note. The writer had known Lowenstein as a fellow IREer; had been at the American Telephone and Telegraph Company's headquarters on radio matters during all this time, and had been aware of company contacts with Fritz, but without knowing the subject matter. Imagine then, his surprise upon meeting Lowenstein one lunch time in 1918 in the German restaurant beneath the Woolworth Building, and being shown a check to Fritz's order from the American Telephone and Telegraph Company for the $150,000! To the question of what was it all about, he cheerfully explained, and then observed in his quizzical way, "And to think, for just a little dry battery!" The appropriate rejoiner would have been, "But in the right place!" Fritz was so pleased with his accomplishment that he carried the exhibit, a photostat, around with him to show his friends, as an Indian would a scalp! Had the writer not known Fritz personally he would have been unaware of the telephone company's payment, for so unheralded had it been at headquarters! Incidentally, Fritz's insertion of the audion amplifier in the receiving branch of his office telephone in 1911 constituted the first application of that revolutionary device to the Bell System, sub rosa as it was!

The von Lieben Group

Candor requires that we recall at this point something of another group of inventors whose work with the cathode-ray tube was contemporary with that in the U. S. and had been directed from the beginning at the problem of the telephone repeater. The Austrian Robert von Lieben patented in Germany in 1906[19] a telephone repeater comprising a thermionic three-element beam-deflection tube intended to be of high vacuum. It was scientifically sound but not successful. The inventor, with two associates, Reisz and Strauss, fell back upon the gaseous, ionic, type of thermionic tube beginning about 1909. In 1910 several forms were patented in Germany.[20] One of these used an intervening grid for control and was applied for in the U. S. on January 30, 1911, and issued September 17, 1912, No. 1,038,901. It was this patent as well as earlier de Forest audion patents, that was cited against Lowenstein. Thereby he was prevented from covering the audion as an amplifier broadly, his invention reducing to the negative grid feature.

While it seems clear that Lowenstein started on his amplifier quest from de Forest's audion in 1909–1910, his more successful renewed pursuit of it in 1911 may well have been stimulated by some knowledge of the von Lieben work having seeped across the Atlantic. He is known to have followed the German-language literature, and Hammond's visit to Germany in the summer of 1911 had made Hammond "quite familiar with the art in Europe" as he wrote Thompson. Since Lowenstein did not get the blocking condenser out of the grid circuit until late in 1911 (by which time the von Lieben group already were in the U. S. Patent Office), he cannot be credited with having been the first to have arrived at the grid thermionic amplifier even in the U. S. But he *was* the first with the type of device that was to win out. The initial promise of the von Lieben mercury-vapor ionic grid tube proved to be chimerical, for the device was erratic and noisy and did not lead to the final answer, the high-vacuum tube. Fortunately for de Forest and Lowenstein, the audion did! Actually, Lowenstein and Hammond, by coming into the picture when they did, alerting de Forest, and leading on to the two large electrical companies, performed a major service.

High-Vacuum Tube

Singularly enough, as the paper indicates, both of these big companies, the American Telephone and Telegraph Company (and its associates of the Bell system), and the General Electric Company, learned of the audion about the same time, late October and early November, 1912. Each went immediately about the improvement of the mysterious little tube, unknown to the other. Although up to that point the mode of operation had been a mystery, and the tube was flimsy, erratic (hardly any two were quite alike), and unable to carry a material load, within a year or so each company had mastered the device and was producing a tube characterized by regularity and reproducibility, whereby it became the revolutionary electronic tool it did. The contribution of these companies was, then, a major one. It followed from the application of the scientific knowledge of the time to the temperamental little tube, first in diagnosing its troubles, and then in applying the remedies: high vacuum and higher voltage, better filament emission and longer life, and circuits properly designed to go with it. No wonder these two great companies locked horns over the great high-vacuum improvement when the General Electric Company sought and obtained a patent on it on behalf of Langmuir. Arnold more modestly had regarded his high-vacuum tube as an application of scientific knowledge rather than invention. The contest continued many years, with the Supreme Court finally sustaining Arnold's view. He was given credit for having anticipated Langmuir in November, 1912, and de Forest was recognized to have gone part way toward the high-vacuum tube even earlier without knowing the physics of it. The Langmuir patent was invalidated on the basis that, ". . . the relationship of the degree of vacuum within the tube, to ionization, and hence to the stability and effectiveness of the discharge passing from cathode to anode, was known to the art when Langmuir began his experiments." The reference cited is a paper by Lilienfield.[21] It is pointed to as having ". . . made a complete and explicit disclosure of the essentials . . .". The decision went on to recognize that, "Lilienfeld also deduced from meter readings and stated the 3/2 power relation of current to voltage, as Langmuir later stated it in his patent. From this the conclusion is inescapable that Lilienfeld knew and stated, in terms which could be understood by those skilled in the art, that in a high vacuum the current produced is under control, stable, and reproducible; and, as he employed high voltages, that higher power levels of the discharge may be obtained . . .".[22]

To return more directly to the Hammond-Purington paper: it must have been early November, 1912, rather than "in late Oc-

[19] German Patent No. 179,807; patented March 4, 1906; issued November 19, 1906.

[20] German Patent No. 236,716; patented September 4, 1910; issued July 11, 1911. Corresponding U. S. Patent No. 1,059,763; applied for January 30, 1911; issued April 22, 1913.
German Patent No. 249,142; patented December 20, 1910; issued July 12, 1912. Corresponding U. S. Patent No. 1,038,901; applied for January 30, 1911; issued September 17, 1912.

[21] J. E. Lilienfeld, "The conduction of electricity in extreme vacuum," *Ann. Phys.*, vol. 32, no. 9, pp. 673–738; 1910.

[22] (664) de Forest Radio Co., Petitioner, vs General Electric Co. (283 U. S. 664–686). Published in Book 75, "Cases Argued and Decided in the Supreme Court of the United States, October Term, 1930," The Lawyers Cooperative Publishing Co., Rochester, N. Y., vol. 131, pp. 1339–1349.
Also reported by W. R. Ballard, "The high vacuum tube comes before the Supreme Court," *Bell. Labs. Record*, vol. 9, pp. 513–516; July, 1931.

tober," that de Forest was in Gloucester, for he had gone first to the Bell people and was with them the last two days of October.[23]

Fig. 8 of the paper shows a concentric form of vacuum tube structure (with axial filament surrounded by cylindrical grid and plate), a design attributed to G. W. Pierce. As if it were new, Hammond referred it to the General Electric Company as "the proper triode design." But such form of tube was not new; it was to be seen, along with measured E-I characteristics, in a German Scientific paper.[24]

Modern Intermediate Frequency Circuitry (Section IV)

This section of the paper recounts some interesting early inventing by Hammond, but by not fully revealing other contemporary developments of intermediate frequency circuitry, gives the impression of that technique having originated largely in Hammond. Actually, it started before him and developed without knowledge of his activity, secret as it was.

In a patent interference Hammond was awarded a claim which he interprets as giving him "the broad subject matter" of intermediate-frequency circuitry.[25] The claim is quoted as reading:

> A carrier wave transmission system comprising means for receiving and detecting the energy of a modulated wave, means for selecting a component of said detected energy, and means for detecting said selected component.

Thus, the claim is for tandem detection-selection-detection. The paper asserts, "The entire principle of IF selectivity is expressed by the words 'selecting a component' regardless of whether the unselected components were to be utilized otherwise as in multiplex reception, or were to be discarded as in simplex telephonic reception."

What is disclosed in Hammond Patent No. 1,491,772 (1912–1924), of which the above is claim 46? The modulated "carrier transmission wave" is simply that of an intermittent spark discharge of definite group frequency. That group frequency is recovered in the output of a detector, is selected and then detected again, down to the signal frequency. The receiving selectivity is enhanced by tuning to the spark frequency as well as to the radio frequency.

Now this addition of selecting the spark frequency after detection and then rectifying it to obtain the signal frequency, was not new as of 1912. In 1909–1911, the Telefunken singing-spark, quenched-gap, system of wireless telegraphy which contained it was well known. The receiver comprised: a radio-frequency tuner, a detector, an amplifier sharply tuned to the spark frequency of about 500 cycles, a second detector, and a telegraph signal recorder. (The tone-frequency signals, instead of being rectified, could be read in headphones or on a loudspeaker.) The amplifier element was electromechanical, a stretched steel wire tuned to the spark frequency drove a microphone, and three such elements in tandem made up the amplifier, highly selective as it was. The system was described fully in the German technical press of 1910–1911 and in *The Electrician of London*, page 249, November 24, 1911. Since Hammond was familiar with German developments of the time, he must have known about it. A transmitting and receiving set was imported into the U. S. by the Telefunken Company of America and exhibited and offered for sale at their quarters in the little tower of the Trinity Building at 111 Broadway, New York. The present writer was employed by this American subsidiary of the Telefunken Company in 1909–1910 and helped set up and operate the apparatus. Among the U. S. military people to whom it was shown was the then Lieutenant G. C. Sweet, U.S.N. What became of this particular set of apparatus is not known, but other quenched spark sets were sold to the Army and the Navy, and altogether the system became well-known at the time. Hence in allowing to Hammond, as of 1924 on the basis of a 1912 application, this claim which reads on the Telefunken system, the Patent Office must have overlooked prior art. In view of it Hammond cannot be credited with originating the double-detection technique, starting, as it did, with audio-frequency IF.

Of Alexanderson's 1912 tuned-radio-frequency receiving circuit shown in Fig. 12, it is said that *if* the tubes of the first stage were all detectors (they being in parallel), "then the system would be of the intermediate frequency type . . .".[26] But there was then no basis for calling them detectors; the "if" is a pure supposition of the authors, made in the light of later developments. Hence the claim that Hammond's October, 1912, conference with Alexanderson had "disclosed the ultimate selective receiver with double detection . . ." (meaning superheterodyne) impresses one as unjustified.

While on this matter of Hammond's 1912 approach to the double-detection, IF, technique, it is to be observed that the twice-tandem-interrupted kind of spark transmitter of Hammond Patents No. 1,491,773 and No. 1,491,774, is shown in the little book by Miessner where one reads: "Fig. 82 illustrates a type of transmitter-receiver unit suggested by the writer in 1911."[27]

Another claim[28] for a "first" must be corrected:

> The intermediate-frequency principle was first applied outside the laboratory to the solution of a World War I communication problem of high military importance.

The apparatus is said to have been

> . . . constructed by the Hammond Laboratories in 1917–18,

and

> Delivered to the U. S. Army at Tours, France, . . . on October 10, 1918.

Actually, the IF principle had been applied "outside the laboratory" a year earlier here in the U. S. This was the short wave multiplex radio telephone system developed by the Western Electric Company, more directly by R. A. Heising, in 1916 and installed on two U. S. battleships. It is described briefly in the Craft-Colpitts paper on "Radio Telephony" given before the AIEE on February 21, 1919. Not only was this ahead of Hammond's military application, but the technique was superior, enabling a plurality of carrier channels of intermediate frequency taken from the wire carrier art, to be conveyed over a radio carrier.

Fig. 14 of the paper shows the double-detection circuit of the 1917–1918 Hammond Chaffee system, which was covered by two patents.[29] Only one of these patents shows feedback on the first stage, namely the Chaffee one, and it specifically says it is to increase sensitivity and that the feedback should *not* be allowed to oscillate. Yet the authors in afterthought say it was "usable" for heterodyne reception, and assert: "Structurally, therefore, the receiver was of the most general 'superheterodyne' variety, since both detectors could be, and during adjustment often were, of an oscillatory nature." Of course both detectors were "of an oscillatory nature," detection of oscillations being their function, and they would even tend to self-oscillation. But the first detector was not used in the self-oscillating condition; the Chaffee patent enjoined against it. Thus, one sees that the authors use "weasel words" to give the impression they had a true superheterodyne in 1918, whereas they did not.

The first to arrive at the true superheterodyne and apply for a patent on it, was one Lucian Levy of Paris. He invented it as a highly selective antistatic receiver in 1917. Soon thereafter E. H. Armstrong learned of Levy's receiver while in Paris with the AEF, the present writer has learned from Levy. Armstrong's acquaintance with the principle may have started in New York with the Western Electric Company before he went abroad, but his full appreciation of it probably stemmed from Levy more than from Hammond as the present authors suggest, although he probably knew also of the Hammond-Chaffee system. Upon returning to the U. S. after the war, Armstrong sought to exploit the superheterodyne as a means of amplifying and receiving the higher frequencies, and managed to be allowed a patent. But he had nothing new in principle and finally lost to others, mostly to Levy, all the patent claims. In 1919 Levy had offered his American rights for sale to the French house of the Western Electric Company, namely La Material Telephonique. In this way knowledge of his work came to the attention of Bell System engineers. They themselves had evolved the principle of frequency step-up-and-down, but so gradually and generally that they had not appreciated all its inventive features. But upon learning what Levy was patenting they did appreciate it as a high-gain, highly-selective, stable receiver, and purchased his American patent application. Prosecution of it in the Patent Office resulted in Levy securing the definitive patent in the U. S. to the superheterodyne as a means of amplifying and selecting, prevailing over several contestants, including Armstrong and Hammond. (Patent No. 1,734,038 of 1918–1929.) The writer in recent years asked Levy about his invention

[23] Footnote 1, p. 1198.
[24] O. von Baeyer, "Ueber langsame Kathodenstrahlen," (Concerning low-velocity cathode rays), *Phys. Z.*, vol. 10, pp. 168–176; March, 1909.
[25] Footnote 1, p. 1203.
[26] Footnote 1, p. 1201.
[27] B. F. Miessner, "Radio Dynamics," D. Van Nostrand Co., Inc., New York, N. Y.; 1916. See ch. 17, "A means of obtaining selectivity," p. 145.
[28] Footnote 1, p. 1201.
[29] Footnote 1, p. 1201, reference 50.

in relation to Hammond. In a letter of June 14, 1955, he replied: "Hammond's works were entirely unknown in France in 1917."

In the year 1920 the present writer, with the American Telephone and Telegraph Company, became aware that there was developing a considerable technique in the stepping of channels up and down in the frequency scale through modulation and demodulation in conjunction with amplification and frequency selection. He drafted two reports calling attention to the situation. They showed the existence of some fifteen patent applications internal to the Bell System, and some six inventions outside the Bell System, those of A. V. T. Day, Hammond, Meissner (the German), Levy, Alexanderson, and Armstrong. Since the Bell System engineers were early in leading into this technique, a listing of their contributions will illustrate the evolution that occurred quite independently of Hammond:

1) Homodyne reception, *i.e.*, zero-beat heterodyne, invented by B. W. Kendall in 1915, Patent No. 1,330,471 (1915–1920). Used in the trans-oceanic radio telephone tests of that year, including the present writer's reception at Pearl Harbor, T. H.
2) Single-sideband transmission, wherein the carrier is resupplied at the receiving end by a zero-beat oscillator, invented by J. R. Carson in 1915, in conjunction with the same radio telephone development. Patent No. 1,449,382 (1915–1923).
3) A "static" neutralizing system receiving on two frequencies, beating one down, the other up, to a common frequency, for balancing. Espenschied Patent No. 1,309,400 (1916–1919).
4) Multiplex radio telephony wherein three intermediate carrier channels are modulated en-bloc upon a radio carrier, then demodulated, selected, and finally detected in individual channels. Installed on two U. S. battleships in 1916–1917, R. A. Heising Patent No. 1,633,100 (1916–1927). This same year B. W. Kendall pointed out that Heising's multiplex system could operate with carrier suppressed, if resupplied at the receiving end by a zero-beat oscillator (recalled to the writer by Heising in 1957).
5) World War I intervened.
6) By the end of 1919, Carl R. Englund was using at Elberon, N. J., in the ship-to-shore radio telephone development, a three-channel superheterodyne receiver, according to the remembrance of Harald T. Friis and the writer.
7) Superheterodyne receivers were used on both the ship and shore ends of the development, 1919–1923. System described in paper by Nichols and Espenschied.[30]
8) Double modulation and double detection were used in the radio telephone link established in 1920 between Catalina Island and the mainland, California. Carried a superimposed telegraph channel. (PROCEEDINGS OF THE IRE, December, 1921, and *Bell Telephone Quarterly*, October, 1923.)
9) About this same time, 1920, a superheterodyne receiver was employed to realize sharp selectivity and high gain, in a radio printing telegraph demonstration between New York, N. Y. and Cliffwood, N. J., for the delegates to a preliminary international conference on electric communications.[31]
10) 1922–1923, a superheterodyne field strength measuring set, made portable by means of loop and "peanut" tubes requiring modest battery, used in ship-to-shore development, later in broadcasting.[32] Forerunner of the 4-A broadcasting receiving set referred to below.
11) 1922–1923, appearance of the first commercial superheterodyne developed for broadcast reception, the Western Electric 4-A. A copy of an engineering report on its development was given to Dr. Alfred N. Goldsmith of the Radio Corporation of America in October, 1922, and a model of the receiver itself was given to him a few months later for test purposes. This receiver was so superior to anything else available at the time that it " . . . literally gave Elmer E. Bucher and others responsible for RCA sales the jitters," said Gleason L. Archer in his book, "Big Business and Radio" (1939, page 92).

Thus it is apparent that IF technology came into being and went into service quite independently of Hammond's more secret efforts in the field.

Frequency Modulation and Related Systems (Section V)

As the paper indicates, the idea of FM was of long standing, without meeting much success until practiced at the higher frequencies with a correspondingly wide frequency swing.

A Hammond patent is cited[33] which undertook to transmit radio telegraphy by the familiar frequency-shift keying of the Poulsen arc while simultaneously modulating both frequencies for telephony. But the arrangement was so crude as to be substantially inoperative: telephone reception would suffer key clicks; telegraph reception in the earphones would experience interference from the telephone channel. Such a "paper patent" can hardly be said to have "established that two independent communications could be sent on the same band . . . " (in fact de Forest had already done that). Certainly the disclosure of the patent was not what founded the modern practice of transmitting two chrominance signals in color television.

The presentation of the Chaffee transmitter of Fig. 16 as part of a "noise-reduction system" is misleading since the noise it undertook to reduce was that arising in the transmitter itself, not that of the transmitting medium.

It is appropriate for the authors to recall something of how wide-swing FM arose from the advance of radio to the higher frequencies, where the "natural atmospheric disturbances were of lessened importance." As tube transmitters were pushed to these higher frequencies (of the order of 50 mc), the modulation of a radio telephone transmitter tended naturally to swing the frequency. Appearing initially as a fault, the making of a virtue of this effect was a natural second thought. Chaffee of the Bell Telephone Laboratories thus sought to utilize it and devised a receiver for an FM system. The printed announcement of a paper[34] he was to give was followed immediately by a press release by Prof. E. H. Armstrong of his own invention of FM, now so well-known. In the public demonstrations made by Armstrong he compared the high-frequency FM channel with an ordinary broadcast channel, giving the impression that all the noise improvement was due to his FM system, whereas perhaps half had been bestowed by Nature!

Altogether, the attainment of the higher frequencies by means of the vacuum tube was the primary force in bringing about modern FM, the inventors being those who were on the stage at the time seeking the new. No less is the honor owed to those who, through "inspiration and perspiration," really gave it to the world.

LLOYD ESPENSCHIED
Retired Consultant
99 82nd Road
Kew Gardens 15, N. Y

[30] H. W. Nichols and L. Espenschied, "Radio extension of the telephone system to ships at sea," PROC. IRE, vol. 11, pp. 193–242; June, 1923.

[31] R. A. Heising, *J. Franklin Inst.*, vol. 193, pp. 97–101; January, 1922.

[32] R. Brown, C. R. Englund, and H. T. Friis, "Radio transmission measurements," PROC. IRE, vol. 11, pp. 115–152; April, 1923.

[33] Footnote 1, p. 1200, reference 43.

[34] J. G. Chaffee, "The detection of frequency modulated waves," presented at Washington, D. C., April, 1935. Published in PROC. IRE, vol. 23, pp. 517–540; May, 1935.
———, "Application of negative feedback to frequency modulated systems," PROC. IRE, vol. 27, pp. 317–331; May, 1939.

Rebuttal by John Hays Hammond, Jr. and E. S. Purington*

On February 3, 1958, we received the uncorrected nine-page galley sheets of a paper "Critique of the Hammond-Purington Paper Entitled 'A History of Some Foundations of Modern Radio-Electronic Technology'," by Lloyd Espenschied, a Fellow of the IRE. We appreciate the courtesy of the Editorial Board of the PROCEEDINGS in permitting us to publish this Rebuttal in the same issue in which the Critique also appears.

This Critique contains both material relating to and not relating to that con-

* Received by the IRE, March 31, 1958.

tained in our previous paper. We do not choose to comment upon the extraneous material except when it appears to have an indirect bearing upon our own material. Our critic has long been known to us as a member of the IRE History Committee. As such he has been given, in the past, much material from our files in which he had expressed interest by correspondence. We regret that we did not have the opportunity of commenting upon his present paper before it was presented for publication, and that we are now compelled to take up valuable space to clear up matters that could have been attended to by a continuation of our personal correspondence. In presenting our paper, we expected comments in addition to those kindly furnished by the reviewers of our first submitted draft, and we would have welcomed constructive criticism of our effort to establish radio-electronic history upon a more correct basis.

For purposes of later identification, we will number the items upon which we wish to comment consecutively in the order of appearance in the Critique. We will then give for each item a quotation from the Critique, to assist a reader in locating the material to which we are responding. Thereupon will follow our rebuttal or comment for each case. At the end of our rebuttal or comments on all items, we will list such references to published or unpublished material as may seem appropriate, with reference numbers for each documentation corresponding to the items to which they pertain. Moreover, we will be glad to supply copies of listed unpublished material to the Editor of the PROCEEDINGS, and to the Chairman of the IRE History Committee. The items upon which we wish to comment follow.

I. INTRODUCTION

1) *Critique.* " . . . the roots of our modern technology trace back generally to sources other than the Hammond Laboratory."

Comment. Many of the roots that nourished the work of the Hammond group and its contemporaries were recorded in our paper: the pioneering work of Wilson and Evans, Tesla, Shoemaker, in basic radiodynamics; of Edison, Fleming, De Forest in basic electronics; of Tesla and Fessenden leading to the development of basic intermediate frequency circuitry; and the initial thinking of Gueroult, Taylor, Helmholtz, Ehret in the field of frequency modulation. The later work of the Hammond group and of its contemporaries in these four fields has been set forth on the basis of our best knowledge.

2. *Critique.* "Hammond's work was conducted in secret, as the authors aver, ..."

Rebuttal. Hammond's early work for radiodynamics was conducted in secret in the same sense that the Manhattan Project in atomic energy was conducted in secret. It was not kept from the military, for example, but parts of the work were kept from Congress by the military. All that we averred was that "publication of technical and historical information was highly limited by governmental and self-imposed restrictions." The governmental restrictions were mainly by act of Congress requiring certain patent applications to be placed in the secret archives of the Patent Office, as set forth in the paper. Self-imposed restrictions were for the purpose of observing the proprieties and keeping faith with officials who expressed their convictions very freeely in defense matters. In this rebuttal, we are lifting a self-imposed restriction in one matter, because we know the officials quoted would so desire it under the present circumstances.

Radio-electronic work mainly of defense interest has always been either developed in close cooperation with the military, or in the initial stages has been brought to the attention of the proper Governmental authorities. Radio-electronic work mainly of commercial interest has had a proper outlet to the industry through conferences, demonstrations, and patent arrangements. For example, consider the early work leading up to intermediate frequency circuitry. In February, 1912, even before the filing of a patent application, information of military and commercial value was given both to B. F. Miessner, temporarily of the Lowenstein-Hammond laboratory, and to Dr. L. W. Austin of the Navy Department. Thus in a Miessner letter[1]: "Mr. Lowenstein had kindly loaned me your letters to him concerning the new selective system. Contrary to my usual custom, I believe the invention a good one. It, at least, is a very good way of dodging the Tesla and Fessenden patents. . . ." The manner of referring to the Tesla and Fessenden contributions, of course, was not the way that Hammond had put the matter, but serves to identify[2] the material under discussion. Also, in a later letter[3]: "I am glad to learn what Dr. Austin thinks about your new selective system and the probability of its being applicable for commercial as well as tel-automatic work. Kindly accept my thanks for the letter. I believe that by being in touch as closely as possible with all phases of the work I can tackle my part of it in the proper way."

Thus there was no improper holding back of information, either from a top level Government expert, or from a technician of a subsidiary laboratory.

II. THE RADIODYNAMIC TORPEDO

3) *Critique.* " . . . but singularly omitted from mention is the one who received from the Patent Office the underlying claims, ..."

Rebuttal. The claim cited is not an underlying claim because of the clause "as set forth," without which the claim would probably not have been allowed, since it would then have read upon the wire-controlled torpedo covered by patents long since expired. A very similar claim, also with the restriction "as set forth," is in the Tesla patent, our previous footnote 2, as follows:

"5. The combination with a source of electrical waves or disturbances of a moving vessel or vehicle, and mechanism thereon for propelling, steering or operating the same, and controlling apparatus adapted to be actuated by the influence of said waves or disturbances at a distance from the source, as set forth." Neither the cited Fiske nor Tesla claims were infringed by Hammond in his 1914 *Natalia* installation, because of the "as set forth" clauses. Wilson and Evans, with a December 29, 1897, British filing date, very probably had an effective date of invention prior to both Tesla and Fiske. The precise reason that Fiske was not named by us as a pioneer is because of our understanding that from a chonological standpoint Wilson and Evans preceded him, and from a practical standpoint of experimental demonstration, Wilson and Evans and Tesla built radiodynamic models controlled from a distance. In the latter years of their effectiveness, the Fiske patents were owned[4] by the Western Electric Company. Presumably because of the response to the cited Hammond letter, it was regretfully entered into the record[5]: "I was informed that the patent was never developed into an operating machine." Fiske's works in Navy fields such as range-finders and torpedo-planes were much admired by Hammond, but not even personal friendship would be a reason for naming him as a pioneer in the field of radiodynamics.

4) *Critique.* "In the summer of 1915, Hammond was selling to a Congress worried by the European War then raging, his system of wireless control of torpedoes."

Rebuttal. This is a gross exaggeration. In March of 1915, the approach to Congress was not by Hammond but by Secretary of War Garrison[6] who urged that the Hammond inventions be given favorable consideration. But the Congressional leaders considered it then too late to enter the matter on the agenda for that session. General Weaver, Chief of Coast Artillery, then advised Hammond that if he so desired, he could now take his inventions to a better market abroad (as Hiram Maxim had done), without deserving any censure at home. Mr. Hammond elected to await the next session of Congress, and the Fortifications Committee of the House held early hearings from January 24 to February 10, 1916. Both the Army and the Navy experts reported very favorably in a hundred pages of printed record, our previous footnote 14.

Even in the summer of 1916, Congress was not worried about the war, as long as it raged only in Europe. Its concern was that sooner or later there would be a winner of that war, and that foreign battleships might eventually appear off our coasts to bombard our cities. The Hammond invention was of great interest because it promised a method of sending a powerful guided missile out to sea under precision control from an aeroplane, much farther than was possible with the ballistic missiles from coast defense guns. Senator Townsend of Michigan[7] expressed it concisely: "Now it seems to me that in these uncertain times, in these times when we are preparing for defensive war, the United States Government cannot

[1] B. F. Miessner to Hammond, February 6, 1912.
[2] Disclosure of Hammond, leading to U. S. Patents 1,522,882 and 1,491,772.
[3] B. F. Meissner to Hammond, February 12, 1912.
[4] Congressional Record, 64th Congress, 1st Session, p. 10875, col. 1; June 13, 1916.
[5] J. H. Hammond, Jr., "Telautomatics," vol. 2, p. 35; 1910–1912. Copy available in Navy Dept. Library.
[6] Congressional Record, 64th Congress, 1st Session, p. 11785, col. 1; June 30, 1916.
[7] *Ibid.*, p. 11667, col. 2; June 28, 1916.

afford to neglect an opportunity of this kind." The leisurely debate appears in the thirty-three pages of the Congressional Record in which the matter is covered, over the period June 13 to June 30, 1916. Members of Congress were quite unanimously willing to make the initial appropriation of $30,000 by which a Board of six Army and Navy officers was expected to find whether the guided missile principles developed by Hammond would be of benefit to the country. The debate in the Senate was mainly whether the Board should be required to report back to a later session of Congress, or should immediately be provided with conditional funds so that it would be able to proceed without delay if it considered the inventions worth adopting into service.

One of those who may have looked beyond the immediate horizon was Senator Stone of Missouri, who spoke[8] as follows:

"What is claimed for it? What will it do? In a word, this is what it is claimed it will do, namely, that through the operation of electrical energies controlled by the devices of this invention, an explosive body may be directed in its course until it comes in contact with a given body, stationary or movable, against which it is directed."

Are we not now, forty-two years later, seeking a device to do just that, with the body against which it may be directed not a battleship twenty-five miles offshore, but a ballistic missile from across the entire ocean?

The lack of real concern for the war raging in Europe, even as late as ten months before our entry into it, is shown by the discussion[9] as to where a plane was to be had so that the Board could make the guidance tests of the Hammond torpedo:

Senator Brandegee: "Mr. President, I was going to ask the Senator this question: Inasmuch as the House provision provides for a Board of Army and Navy experts to make whatever tests they think ought to be made, and to report upon this purchase—and the machine cannot be bought unless they should report favorably—and inasmuch as the Government owns an aeroplane for its Army, officers and aviators can operate and make the test without any expense at all, without purchasing an airship, why does not that fulfill the conditions?"

Senator Lane: "I do not think this Government owns an aeroplane which will travel through the air with any safety to the navigator: in fact, most of them have come to earth and caused a loss of life of the helmsman. I think we are practically out of aeroplanes: at least, I am so informed, although we have spent millions of dollars in building them. We ought, however, to build another type, and we should do so promptly."

Senator Brandegee: "I will say to the Senator from Oregon that I saw a very good-looking aeroplane the other day over at the Senate Office Building—it was a Curtiss machine, I believe, or a Wright machine—which the Government, I suppose, can purchase, if it so desires, for a very moderate sum. Aeroplanes, as I am advised, cost from about $7500 to $100,000, according to size and depending on the kind desired."

Senator Lane: "I also saw the aeroplane to which the Senator from Connecticut refers. It was in a good, safe position; it was near the ground, and I climbed aboard of it."

Congress was not too concerned about the war raging in Europe, even as late as the summer of 1916. It was not until after the election of November, 1916, that the country realized that such slogans as "We are too proud to fight" and "He kept us out of war," had contributed to bringing about the worries of Congress in the summer of 1917.

Actually, in the summer of 1915, while waiting for another session of Congress, Hammond was busy[10] with other activities relating to the firing of standard naval torpedoes. In a letter of August 23, 1915, Captain W. S. Sims, Commander, Destroyer Squadron, Atlantic Fleet, advised the Secretary of the Navy: "Mr. John Hays Hammond, Jr., is the inventor of an appliance to facilitate the fire control of torpedoes. He has explained the principle of the device before the Destroyer Squadron Commander and the Squadron Torpedo Officer, Lieutenant Commander J. V. Babcock, and in our opinion the device merits the Department's serious consideration. . . . It is therefore strongly recommended that Mr. Hammond be given every opportunity and facility to prosecute his experiments." Naval Ordnance then financed the work, equipment was built by the Cummings Machine Works in Boston under the supervision of A. D. Trenor of the Hammond group, and the system is a fundamental method of torpedo firing.

5) *Critique.* "Two World Wars have now occurred with no military use of the radio-controlled torpedo; it is just as well except for the futile expenditure of technical effort and public money."

Rebuttal. The first part of this statement is in error, since the meaning of "torpedo" given in the opening sentences of the section is sanctioned by Congressional and military usage. Most certainly, the inventions acquired by the Government cover applications to both water-surface torpedoes and aerial torpedoes, as well as to the underwater torpedo by which the principles of missile guidance were required to be demonstrated. The "Azon" bombs of World War II[11] and the "Glider" bombs[12] used by the U. S. Air Force in wrecking the railroad yards of Cologne are examples of "aerial torpedoes" operating by the Hammond method. The "Stingray" boats used against the Japanese and the drone-boats used against the Germans[13] are examples of radio-controlled water-surface torpedoes. The Hammond work with underwater torpedoes terminated successfully in 1931, and any failure to use them in World War II is not chargeable to Hammond. When the U. S. Congress failed to consider the 1915 recommendations of Secretary of War Garrison, Hammond was released by General Weaver from any moral obligation to deal further with the U. S. Government, and there were offers from abroad to take over the inventions and devices of the Hammond Laboratory. If Hammond had not elected to continue with the Congress in 1916, it is quite likely that water-surface torpedoes would have been used in Europe during World War I. As it was, the Germans actually did sink a British warship by a surface torpedo under wire control from a shore station.[14]

As to the latter part of the quoted sentence, we assume that what our critic meant was that the technical effort and the public money spent were futile. This is also in error. The same principles of guidance that were developed for underwater torpedoes were also applicable to the control of target ships and airborne target drones. This Hammond contribution alone has been considered by experts[15] to have justified the full cost of the Hammond effort to the Government.

6) *Critique.* "Among the principles claimed to have been developed in the 1910–1914 period is that of the automatic stabilization of the course of a torpedo by means of a gyro."

Rebuttal. No such claim was ever made. We stated as background of the modern principles of missile guidance: "In the absence of a control signal, the torpedo should be stabilized as to course by mechanisms within itself." For the purpose of disclaiming automatic stabilization of the course of a torpedo *per se*, and also of disclaiming any part of the development of the motor-driven gyro, we specifically stated: "Course stabilization had been practiced in naval torpedoes by a gyroscope energized only at the start of a run. But in 1912, ..." The "had been," therefore, very clearly refers to a time prior to 1912, which by our footnote 7 was the date of the initial Hammond concept of the use of a gyro in surface boat control work. Our critic may be sure that if gyro stabilization of the course of a torpedo by itself had been a Hammond invention, we would have used the simple past tense *was* instead of the pluperfect "had been"; furthermore, we would have given a patent number as a footnote. Our critic chooses to read *by Hammond* into the text after the word "practiced," where no such insertion was intended or justifiable.

7) *Critique.* "This development is understood to have been undertaken by Sperry alone, the Navy adopting the system upon its appearance in 1911."

Rebuttal. Gyro-compass equipment was installed upon the *Utah*, the *Wyoming* and the *North Dakota* in the latter half of 1912. On the basis of Navy reports up to March 31, 1913, we considered the work done by the Navy, especially by Chief Electrician England of the *Utah* and Ensign H. R. Saunders of the *Wyoming*, of sufficient importance to compel mention of the Navy as a party to even the technical development of the gyro-compass prior to its adaptation by Hammond for radio-control and other work in the winter of 1913–1914. If we had failed to mention the Navy, we would

[8] *Ibid.*, p. 11795, col. 2; June 30, 1916.
[9] *Ibid.*, p. 11789, col. 1; June 30, 1916.
[10] U. S. Patents 1,388,640; 1,431,140; 1,431,141; 1,431,142; and 1,431,143 to J. H. Hammond, Jr.
[11] J. C. Boyce, "New Weapons for Air Warfare," Little, Brown and Co., Boston, Mass., pp. 225–235; 1947.
[12] U. S. Patent 1,818,708 to J. H. Hammond, Jr.
[13] Authors' previous paper, p. 1192.
[14] Letter of Admiral W. S. Sims to Hammond, November 3, 1917.
[15] Letter of Admiral W. V. Pratt, CNO to JAG, January 24, 1931.

possibly have been criticized from another source.

8) *Critique.* "This modification was rather obvious since the idea of steering a ship automatically from a magnetic compass was old."

Rebuttal. We were writing about engineering, not about ideas. Our critic, as in many other instances, fails to cite any reference by which one may judge whether the engineering was along new and useful lines. The idea of an antiballistic missile is also old, but a tremendous amount of inventive research and development is necessary before the idea gets to the engineering stage, for the modern application.

9) *Critique.* " . . . as if the automatic pilot originated with Hammond."

Rebuttal. Many might consider the gyro-equipment of a naval torpedo to exemplify an "automatic pilot." Certainly Chandler, previous footnote 16, has stated, " . . . we must regard the gyroscope as the compass of the torpedo as well as its pilot." But certainly it is the function of a pilot to change the course of a craft during a run, and the devices of naval torpedos did not provide for that functioning. And the Sperry gyro-compass mechanism did not provide for a connection with the steering engine. We did not emphasize the Hammond contribution to the complete automatic pilot system now used in the navigation of surface vessels and aircraft, since we were concerned mainly with radio-electronics. Now that the issue has been raised, we consider that the officials of the Government involved would approve the lifting of a "self-imposed restriction" and the release of a part of the transcript[16] of a high-level conference of 1916 in which the Hammond contribution was discussed.

"Mr. Hammond: I think that there is perhaps another use which might be of considerable value. I have been in touch with Mr. Sperry about the proposition, and that is the gyroscope control of these boats. We have demonstrated, of course, that the steering is entirely automatic under the control of the gyro-compass, and it is very accurate, in fact a great deal more accurate than any quartermaster would be. In very heavy weather off Gloucester in a fifty-foot boat, we found that a deviation of our course on a compass was very small and better than any of the quartermasters could hold the course, and that even with sudden movements of large waves, that the mechanism responded so rapidly as not to allow the boat to be thrown off the course. It seems that that might have a very valuable application in the future, in the steering of ships in line, and in the steering of submarines, and in the steering of transatlantic vessels to maintain a more accurate course. The mechanism is foolproof, so far as we have been able to find it. Colonel Devine has observed its action for a number of miles.

"Mr. Sherley: What do you gentlemen say as to the value of that, assuming that control is such as has been indicated?

"Rear Admiral Fiske: That is a very old subject, that question of automatic steering of ships, and there are all sorts of opinions upon it. Some people think it is highly desirable to have ships steered automatically, and I am of that impression myself, provided, of course, that the apparatus is of such character that the helmsman, if he was there, in case of danger of collision, could assume control. If there was danger of collision, for instance, you would not want the ship to be steered automatically if a ship were coming across the bow.

"Mr. Sherley: Admiral, what have you to say about that?

"Rear Admiral Benson: I agree with Admiral Fiske, that if you always have a man there. There is always this element of danger if you have something running automatically you are very apt to trust too much to it and take too much risk, but the principle, of course, is absolutely correct. If you have something that is automatic, that can be changed instantly, of course it is very desirable. The only possible danger could be the fact you trust too much to it and leave it.

"General Weaver: I would like to ask Mr. Hammond if it can't be changed instantly.

"Mr. Hammond: It can be changed instantly, because in our work we have a man on the lookout so as to avoid running down targets when we are attempting to hit them, and also to get around the marine laws, because I do not know that it is permissible for vessels to travel without a crew *ad libitum* around harbors. We have found in cases of such emergency that by the mere pressure of a key the gyro-control is disconnected entirely and the control comes under the hand of the man himself. That is, instantaneous.

. . . . . .

"Captain Bullard: In this system that you speak of, which is your system, you only impress the energy on it when you want to change course?

"Mr. Hammond: Exactly.

"Captain Bullard: Otherwise you are set on a given course and the gyro holds it there.

"Mr. Hammond: Exactly.

. . . . . .

"Lieutenant Decker: I might be able to say something there. I have seen considerable service in the Navy and am quite familiar with ordinary steering apparatus on board a battleship. From what I know of the Hammond system and the system used by the Navy, I see no reason to believe that this system could not be applied to the ordinary steering apparatus as installed upon the ordinary battleship, and so arranged that the control could pass from the gyroscope or automatic steering device over to either an electrical device that is controlled by hand, or to the ordinary system as at present installed. In other words, the connection between the gyroscope control and the ordinary control is so flexible that it could be changed instantly, with the mere throwing of a switch or depression of a key."

Five years later, Admiral Bullard was in charge of the installation on the target ship *Iowa*, which to our best knowledge was the first capital ship to be fitted with automatic pilot equipment. The gyroscope was supplied by Sperry, and the linkage to the rudder was by the Hammond Laboratory and the General Electric Company. The Navy report[17] states that the equipment "will keep vessel on a steady course and is reliable. The instrument will prove of great value in any experiment or operation where vessel must maintain a steady course. It is an expert Helmsman."

The Hammond contribution, therefore, was not in the development of automatic course stabilization *per se*, nor was it in the development of a continuously-running gyroscope. His contribution was to the mechanisms for shifting the course that was stabilized by the gyro, and for switching the system from automatic to manual steering. This point of view is substantiated by some of the patent claims in the three co-filed and co-issued patents cited. Thus typically broad claim 54 of patent 1,418,788 is pertinent:

"The combination with a movable body, of means automatically operative to stabilize said body with respect to a given axis, and means to modify the automatic operation of said stabilizing means and to rotate said body selectively in either direction about said axis."

10) *Critique.* " . . . as if these patents cover course stabilization and the automatic pilot. They do not: they apply only to the application thereto of radio control."

Rebuttal. This statement is in error. There are more than ten claims such as that just quoted in which radiant energy is not mentioned. The patents cover change of the stabilized course by manual as well as by remote radiant energy control.

11) *Critique.* " . . . the arrangement shown. . . is unserviceably crude."

Rebuttal. The word "unserviceably" is highly improper. The patents were cited to support the antecedent statement and to provide a readily-available reference to the basic ideas of this new art. The reference was in a footnote because the techniques were mainly not radio-electronic. As the patents were co-issued, our critic should have at least examined the patents 1,418,789 and 1,418,791 with arrangements more in accordance with our description of the *Natalia* installation, using patented and unpatented improvements. Anyone familiar with the history of inventions knows that practically all important basic patents show devices which years later would be considered crude. The Telephone Company itself developed from the capital value inherent in the crude device shown in the Bell patent application of February 14, 1876. But the fact that such devices are considered to be "new and useful" by the experts of the Patent Office is the best nontechnical evidence that they were not "unserviceably" crude. Note that our critic is not only challenging the conclusions of our own Patent Office, but also the experts who permitted the issuance of the corresponding European patents: French 474,906; British 16,328; German 348,277. It should be noted that this was a period in which even Army and Navy officers retained personal rights even in defense-connected inventions. Actually, these Hammond ap-

[16] "Informal Conference on the Hammond Radiodynamic System for the Control of Torpedoes," Washington, D. C., pp. 15–20; February 9, 1916.

[17] "Special Radio Report, Radio Design Problem No. 70, Radio and Sonodynamic Control," U.S.S. OHIO, p. 8; September 20, 1920.

plications were filed when, as a civilian, he was working informally with the U. S. Government represented at Gloucester by Captain F. J. Behr, and they were drawn with a view of conserving the personal rights of the inventor without disclosing the engineering details necessary for the construction of a militarily-acceptable installation.

The degree of engineering perfection obtained by the end of the year 1914 is covered by the following[18] public record:

"Lieutenant Decker: . . . On this trip we met Mr. Hammond in Boston. That was the latter part of November, 1914. The *Natalia*, the boat on which the installation was at that time, was lying at the wharf at the Navy Yard at Boston. . . . From the Navy Yard we got under way, went out of Boston Harbor under the control steering apparatus, and after we rounded the headlands outside of the harbor, we set a course for Gloucester. The boat was allowed to steer itself in order to test out the reliability of the steering mechanism. The steering mechanimsm performed as nearly perfect as anything could perform. There was not the slightest hitch, and at all times it functioned properly and kept the boat on the predetermined course. I should estimate we ran a distance of something like 15 miles from the entrance to Boston Harbor up to a lighthouse off The Graves, and during that time the boat was not touched, as I remember it, and we did not miss that lighthouse in this 15-mile run more than about a quarter of a mile. . . . As we entered the harbor of Gloucester, the observer on shore saw us. We set the boat for shore control, and the operator on shore made us perform various fancy curves over the harbor and steer around a few spar buoys. During the whole of the test, while I was on the boat, I did not see a single thing go wrong that would in any way have disabled the boat or taken it away from the control of the operator."

12) *Critique.* "The man who pioneered, and produced, the automatic pilot, was Elmer A. Sperry."

Rebuttal. This is in error. Any device which can conceivably be termed an "automatic pilot" must be one which has to do with steering, since without the word "automatic," a pilot is[19] "the steersman of a ship; that one of a ship's crew who has charge of the helm and the ship's course." Our critic has cited the "aeroplane stabilizer" developed in 1913–1914 to support his statement that Sperry pioneered the "automatic pilot." But he failed to observe that the Sperry device did not stabilize the course of the aeroplane, but functioned solely to maintain the plane at a suitable small angle with the horizon while the course of the plane was steered by a human pilot.

By attempting to set up Sperry as the pioneer, our critic now concedes that Obry and Whitehead who developed the course stabilizer for naval torpedoes did not thereby pioneer the "automatic pilot," presumably because the device was neither continuously running nor alterable during the run. Likewise, he concedes that whoever conceived the idea of using a magnetic compass as a course stabilizer was not a pioneer, presumably due to lack of reduction to practice or to lack of practical utility. With these two possibilities thus excluded, the pioneer in the field of automatic pilot systems was not Sperry; it was Hammond. The device of the *Natalia* developed in 1913–1914 provided for automatic course stabilization between the controls of the stabilized course, and provided for changing the course manually as well as by remote radiant energy signals. It was the true prototype of the automatic pilot system commercialized ten years later by the Sperry Gyroscope Company for the steering of large ships, technically known as the "Gyro-pilot," but more generally termed the "Metal-Mike."

Sperry's unquestionably basic contribution to many fields of application[20] was his development of the motor-driven gyroscope. In 1911, he successfully demonstrated his first experimental gyro-compass on the U.S.S. *Delaware*, leading to the development of an improved gyro-compass used by all Allied Navies in World War I. Also in 1911, he was working upon the problem of reducing the roll of ships, and cooperated with the Navy in producing equipment used experimentally on the U.S.S. *Worden*. As of 1927, the largest gyroscope installed for ship stabilization purposes was on the Japanese airplane carrier *Hosho*, reducing the roll by a factor of about eight. In 1913–1914, with his son Lawrence and the Curtiss Company, he developed a special gyroscope system for reduction of roll and for the automatic balancing of aeroplanes. With demonstrations in the summer of 1914 in France, the younger Sperry and "The Sperry Gyroscopic Stabilizer"[21] won the $10,000 prize in the "Concours pour la Securite en Aeroplanes." These three Sperry developments of the Gyro-Compass, the Gyroscopic Ship Stabilizer, and the Gyroscopic Aeroplane Stabilizer, were of utmost importance. But they were not automatic pilots, for the simple reason that in all three cases, the course of the craft was held and was changed only by a human pilot.

Hammond's first business contact with the Sperry Gyroscope Company was in July, 1913, in the same month that Hammond filed applications for the three patents basic to all automatic course stabilization, either by radiant energy or with manual control of the stabilized course. Sperry supplied special gyro-compass type equipment specified in a contract with Hammond dated September 8, 1913; this equipment was successfully installed by Hammond and his staff in the *Natalia* and operated in an automatic pilot system over a distance run on March 25, 1914. After this pioneer work, followed by the U.S.S. *Iowa* installation of 1921, the Sperry "Gyro-pilot" began to be manufactured and sold in considerable numbers. In 1925, after an installation on the *Leviathan* and a patent interference with Hammond, the attorneys of the Sperry Gyroscope Company could cite no prior Sperry art that would dominate the gyro-pilot claims of Hammond in the then-issued patents resulting from the 1913 filings. Presumably since these patents were in effect exclusively optioned to the U. S. Government, the matter was not pressed and the Government received the still-active gyro-pilot rights as an added value in its purchase agreement of 1932.

Except for supplying gyro equipment to Hammond in 1913, Sperry was not seriously involved in automatic piloting until about August 16, 1915, when he filed for a patent 1,446,276 on an electrically-sustained azimuth gyroscope. About a hundred of these devices were sold to the U. S. Navy for naval torpedo work. Sperry's difficulties with the automatic stabilizer for aeroplanes were such that he did not give early serious thought to the "aerial torpedo" or the "radio-controlled aeroplane" requiring course stabilization. Disturbed by the problems of radio reception in a plane, in which field he had not been concerned, Sperry bought rights under a Dubilier application of July 10, 1916, later patent 1,383,177. As the Chairman of the Committee on Aeronautics of the Naval Consulting Board, Sperry on April 11, 1917[22] reported upon "the whole Aerial Torpedo proposition," and within a few days was ordered to proceed to construct Aerial Torpedoes capable of carrying 1000 pounds of explosives. By act of Congress, two classes of torpedoes were to be developed, the completely automatic type and the wireless-controlled type. About a hundred test shots were made before the Armistice, at which time quantity production had been started.

Despite this intense effort sustained throughout the twenty months of World War I, the information concerning the lessons learned did not, apparently, penetrate down to Army and Navy workers in radio control of aeroplanes in the early post-war period. Early work by the Air Service of the Army was carried out in 1920 under the direct supervision of Lieutenant R. E. Vaughan, and literally started from the ground up. Hammond contributed to this development by supplying[23] security-type equipment "with a view of using it in connection with the control of airplanes by radio, the noninterferable characteristics being especially valuable for this work." Tests proved the selectivity and secrecy features of the equipment, and that control up to 40 miles was possible from a ground transmitter. It is noteworthy that in their early post-war work, both the Army and the Navy were hopeful of successful aeroplane control either with no special automatic stabilizer, or without the use of a gyroscope.

In this post-war period, patent interferences developed in the field of aeroplane control by radio, mainly between the Sperry application 207,786 filed December 18, 1917 to cover his wartime aerial torpedo work, and two Hammond patents pending based upon applications of 1914 and 1915 resulting in patents 1,568,972 and 1,568,974 issued subsequent to the interference. As a result, Hammond received the priority, and since his Government obligations were solely in

[18] Our previous paper, footnote 6.
[19] The Century Dictionary, The Century Co., New York, N. Y.; 1914.
[20] "E. A. Sperry, John Fritz Medalist for 1927," ASME Meeting, New York, N. Y.; December 7, 1926.
[21] L. B. Sperry, "The Sperry Gyroscopic Stabilizer," *Flying*, pp. 197–220; August, 1914.
[22] Deposition of E. A. Sperry, U. S. Patent Office Interferences 47,032 and 47,883, p. 44; May 3, 1923.
[23] Contracts 245 and 358, Engrg. Div., Air Service, McCook Field, Dayton, Ohio.

waterborne carriers of explosives, Hammond was able to grant Sperry an exclusive license for developing the airborne field under claims dominating the change of course of an aeroplane under radiant energy control, such as the following from patent 1,568,974:

"29. In combination, a self-stabilizing, self-steering aircraft, and means comprising a radiant energy transmission system for causing said aircraft to make any desired turn in azimuth at any point in its flight."

"30. In combination, a self-stabilizing, self-steering aircraft, means comprising a radiant energy transmission system for causing said aircraft to make any desired turn in azimuth at any point in its flight, and means for automatically banking the craft while turning."

As a result of the Hammond-Sperry agreement of 1925, all later radiant energy airborne-guided missile-type equipment produced by Sperry involving a change of a stabilized course, carried Hammond patent numbers. Pre-World War II radio-guided aeroplanes came to be known as Hammond-Sperry Drones.

Additionally, it is to be noted that automatic pilot systems commercially developed for passenger planes with a pilot in attendance are covered by the basic patents of Hammond filed in 1913, such as that cited in the discussion of Section II–9 above.

Therefore we submit that Hammond, and not Sperry, was the true pioneer in the development of the "automatic pilot" for waterborne craft, and that patentwise, the invention is dominated by patents that went exclusively to the U. S. Government in 1932; that Hammond's gyro-pilot ideas applied in the waterborne field were also applicable in the airborne field, regardless of whether there was a human pilot also available, or whether the craft was radio-controlled; that in the explicit field of radiant energy control of airborne torpedoes in which he was not obligated to the Government, Hammond granted the Sperry Company exclusive rights which it acknowledged and exercised in pre-World War II aerial torpedoes and the like. Hammond pioneered the "automatic pilot" and both Hammond and Sperry produced it. Sperry[24] did not hesitate to regard Hammond as a personal friend as well as an associate in this development.

13) *Critique.* "But ahead of Tesla, apparently, were the two British inventors, Wilson and Evans. . . . The receiving control electromagnet is made dependent for its operation upon the receipt of both channels. . . . "

Rebuttal. The cited patent in Fig. 7 shows such a control magnet. However, there does not seem to be any patent claim specific to this manner of practicing the invention, nor to any security advantages. The Wilson and Evans arrangement would be subject to interference on a "channel" intermediate between the horizontal and vertical polarization "channels": the Tesla system would not so readily be forced by any single channel, since in the Tesla system, the word "channel" is in the usual frequency sense. It is the Tesla system that is the background of the Hammond single-shot FM system of security used on the *Natalia*.

14) *Critique.* "de Forest had devised . . . a diplex system of telegraphy. . . . "

Rebuttal. Such a system is irrelevant to the discussion. Hammond's system was simplex, depending upon the reception of both ends of the transmitted spectrum to establish a single control signal. The de Forest system, apparently, was diplex, with one end of the spectrum for conveying one message and the other end for another independent message. There was no cooperative action between two channels to produce a single signal as in the Hammond security system and as in modern FM reception.

15) *Critique.* " . . . the claim is for a *torpedo*, meaning in water. . . . "

Rebuttal. The words "as set forth" do not appear in the claim, therefore the claim is not limited by the drawings and specifications, but only by the allowable breadth of the words "torpedo" and "energy." We consider the word "torpedo" applies to aerial torpedoes, and that "energy" applies to electromagnetic energy. Note that contrary to the statement of our critic, the word "fuse" is absent from our paper. While the "proximity fuse" principle may apply to airborne devices, the "proximity" principle applies to both air- and waterborne devices. Neither we nor presumably our critic are in a position to know whether or not the proximity principle, in fact, has been applied in both media.

III. The Triode Tube

16) *Critique.* "The quotation is correct, but the assumption that it referred to the triode rather than the diode, as of 1906, is in error."

Rebuttal. On the contrary, our assumption that it applied to the triode both in 1906 and also later is not in error. The Marriott reference in its entirety on this point is:

"5. Audion. This form of detector was used to some extent as early as 1906, but apparently in small numbers until about 1912 when the amateurs became active in its use, and within the last year or more it has been used to some extent by the Government."

Now our critic later states, "It was about that time that the grid audion began to come into some use, 'but apparently in very small numbers' as Marriott said." Since Marriott referred to "this form of detector," and since the form of detector as of 1907 was the grid audion form, as our critic admits, it follows that Marriott was referring to the detector of 1906 as a triode. Our critic does not openly say that the Marriott statement was in error, but does say that we were in error in interpreting it. Our critic, in his first printed discussion of the Marriott paper in the Proceedings,[25] failed to challenge the Marriott statement in this matter, as he must now do.

17) *Critique.* "The grid triode appears to have been invented toward the end of that year or the beginning of 1907."

Rebuttal. The patent application covering the invention of the grid triode[26] was signed by de Forest on December 21, 1906. Therefore, since de Forest undoubtedly used the grid triode in 1906, it appears that the Marriott statement as to dates is just as correct as our interpretation of it.

18) *Critique.* "It . . . issued as a patent February 18, 1907. . . . (There was no time lost in those days!)"

Rebuttal. The grid triode patent referred to issue February 18, 1908. The parenthetical statement shows that the error could not have been due to any typographical error of the printer.

19) *Critique.* "Among those small users, to the writer's knowledge, were a few amateurs. . . . The writer, with two other amateurs . . . attended de Forest's Brooklyn lecture. . . . "

Comment. Our critic, according to "Who's Who in Engineering," joined the engineering staff of the Telephone Company in 1910. There was, therefore, at least one member of the Telephone group who knew of the de Forest triode two years before the Telephone Company, as our critic later states, learned about it in 1912.

20) *Critique.* "The grid audion detector continued for some years solely as a detector."

Comment. The critic here lapses into the early usage of "Audion detector" as meaning a triode tube regardless of the use to which it was put in circuitry.

21) *Critique.* "But they do not tell the whole story and give the impression of Hammond's role having been more than it was."

Rebuttal. There was no need of telling the whole story. The prior attempts at developing the triode were recorded in the first and last parts of the paragraph, showing that Lowenstein still, in 1912, had a lot more to develop. Hammond's immediate interest was the procurement of a better type of "relay-operating rectifier-detector," and in this branch of the work, Lowenstein may have been a true consultant. At least, he never changed the words "Consulting Engineer" on his letterhead[27] when writing about any phase of the ion controller project. Hammond's role quickly became that of an unsecured creditor, but with paper rights in exploiting the triode developments. On the basis of personal friendship, a settlement of financial matters was made with Lowenstein about three months before his sale of the grid bias patent to the Telephone Company, at such a figure that the entire amount received from the sale went directly to Lowenstein as a clear profit. The Hammond role was not exaggerated in the paper.

22) *Critique.* "The term 'controller' or 'ion controller' was Fritz's alias for the name 'Audion' which de Forest had bestowed upon Fleming's tube upon adding to it the 'B' battery."

Rebuttal. This is greatly in error. The Lowenstein "ion controller" was a triode, and not a Fleming diode. Our critic may have confusedly substituted a battery ex-

[24] Letter of Sperry to G. A. E. Lundell, October 21, 1926.

[25] L. Espenschied, "Discussion," Proc. IRE, vol. 5, p. 196; June, 1917.

[26] U. S. Patent 879,532 to L. de Forest.

[27] Letter of Lowenstein to Hammond, November 13, 1911.

ternal to the Fleming valve, where he may have meant a grid within the valve.

23) *Critique.* "The strange thing is that it was not followed up."

Rebuttal. Our conjectures as to why the work was dropped by Lowenstein are stated in the paper. Lowenstein's research was made available to the General Electric Company,[28] with more facilites and competence than Hammond-Lowenstein for carrying out "a systematic investigation of the influence of the vacuum." Dr. G. W. Pierce once recalled to us, "We were not at all sure there was any great future for the triode tube, but felt that any future lay in the development of the hard tube." The hard tube was a General Electric development.

24) *Critique.* "And it is singular that to Hammond, 'The exact nature of the ionic devices and the manner of operation are not known'."

Comment. The technical details may be in the Lowenstein files concerning which our inquiries have been futile. There is a suggestion of a method of regeneration in the book, critic's reference 27, in the figure of a detector circuit for which unusual sensitivity was claimed. (See Fig. 77, p. 133.)

25) *Critique.* "One wonders . . . that the evidence of . . . an oscillation generator . . . was not presented to the courts."

Rebuttal. There is a statement of the oscillatory use of triodes in the book, critic's reference 27. (See p. 179.)

26) *Critique.* " . . . the letter which Hammond wrote the President of that company. . . . "

Comment. This action proves, if nothing more, the Hammond objective of getting radio-electronics on a foundation free from foreign domination. It also discredits the critic's view that all of Hammond's work was conducted in secret.

27) *Critique.* " . . . a copy of the letters was sent to him. . . . "

Comment. We wish to make it clear that the letters were not given to our critic for that purpose.

28) *Critique.* "Arnold later testified . . . 'I was very much astonished and somewhat chagrined. . . . ' "

Comment. Arnold's chagrin must have been matched later by that of our critic who had known of the superiority of the de Forest detector during two years of engineering service with the Telephone Company.

29) *Critique.* "There was ordered from Germany the latest type of vacuum pump."

Comment. This is a point of important historical significance, since it shows the Telephone Company work was much later than that of the General Electric Company in the production of high vacuum tubes.

30) *Critique.* " . . . the company originally could have had the patent for $20,000."

Comment. The Lowenstein patent was used by the Telephone Company in many infringement suits, and presumably made a profit even at the final figure.

31) *Critique.* "Actually, Lowenstein and Hammond, by coming into the picture when they did . . . performed a major service."

Comment. Mr. Hammond, by foreign travel and contacts, realized that the growth of the "Telefunken" and other foreign companies, and their penetration into the United States, could be checked only by interesting large electrical companies in getting into the communication and equipment field. Appearing before the board of the General Electric Company for the purpose of interesting it in an American radio company, he was unable to make the progress later achieved by the efforts of the Navy Department. It is gratifying to learn that his indirect approach to the General Electric Company, the Telephone Company, and the Federal Company is getting to be accepted as a major service.

32) *Critique.* "It must have been in early November, 1912, that de Forest was in Gloucester."

Rebuttal. The premise that de Forest first went to the Bell people is in error. Our documentation is a letter[29] and a telegram[30] which places de Forest in Gloucester in late October, as stated in the paper. The visit was not in connection with the amplifier work of either de Forest or Lowenstein, and the information was casually given.

33) *Critique.* "As if it were new, Hammond referred it to the General Electric Company as 'the proper triode design'."

Rebuttal. The clause "as if it were new" is unjustified. It was an engineering design, expressing the personal views of the members of the Hammond group. This design was not at first followed by the General Electric Company for the reasons stated. Nor was it followed by the Telephone Company in their first wartime type E and J tubes. The original pencil sketches, of which our critic presumably has a copy,[31] carry two dated signatures. These are the signatures of attorneys of the General Electric Company, and not of anyone of the Hammond group. In fact, the only direct indication of the Hammond source of the design is that the material would be recognized as being in the handwriting of Dr. G. W. Pierce, then a consultant to the Hammond Laboratory. Not even he bothered to sign the sketch.

IV. Modern Intermediate Frequency Circuitry

34) *Critique.* "In a patent interference, Hammond was awarded a claim which he interprets as giving him 'the broad subject matter of intermediate frequency circuitry'."

Rebuttal. Our statement rather was, "the broad subject matter in controversy was awarded Hammond." We have very clearly stated our belief that Hammond contributed the selective features of intermediate frequency circuitry, while it was Alexanderson who, due to his development of the TRF amplification idea, contributed the sensitivity features. The withdrawal of the Levy patent application from the interference should not be overlooked.

35) *Critique.* "In 1909–1911, the Telefunken. . . . "

Rebuttal. The Telefunken equipment was not pertinent to the decision in the interference, because what our critic calls a second detector was not a detector. In fact, our critic later states parenthetically: "The tone-frequency signals, instead of being rectified, could be read in headphones or on a loudspeaker." Apparently, our critic's subconscious mind compelled him to use the correct word "rectified" as applied to a tonal frequency signal, and it was only his conscious mind that has attempted to call that rectifier also a detector. As our critic and former advisor of attorneys of the Telephone Company well knows, subconsciously at least, the question of when a rectifier is also a detector was thoroughly discussed in the interference. Our critic gives no patent number for the Telefunken equipment. Its operation in the respect here discussed is unquestionably subservient patentwise to earlier references cited by the Telephone Company in the interference. A brief review of that case appears to be in order.

The patent claim that has been cited originated with Heising or his attorneys. It soon developed that, if patentable, Hammond would win the claim over Heising and over Levy. Levy withdrew. Thereupon, in accordance with usual legal procedures, the Telephone Company, in order to try for a partial victory, attempted to prove its own written claim was actually unpatentable over art prior to both Heising and Hammond. Cited, for example[32] were Fessenden 727,326; Fessenden 752,894; Blondel 824,682; and Scheller (German) 208,836. The Scheller patent was cited especially to upset the claim as to "selecting a component" and the others more especially to upset the claim as to "detecting said selected component." These efforts of the Telephone Company were unsuccessful, and would also have been unsuccessful if the well-known Telefunken equipment had also been cited. If there was anything established technically by the interference, it was that the word "detector" relates to a device involved in the finding of something hidden, and therefore a device acting upon audio-frequency currents already being indicated by headphones or a loudspeaker cannot be termed a detector. If therefore follows that the circuit preceding a second detector must contain currents of a frequency or frequencies above the audible frequency range. Our concept of intermediate-frequency circuits was clearly stated at the beginning of the section, and it is in accordance with present accepted usage.

36) *Critique.* " . . . the Patent Office must have overlooked prior art."

Rebuttal. The Patent Office considered carefully, at the very top level, all the art which the experts of the Telephone Company presented. If the Telefunken equipment had been pertinent, and it was not, any failure to uncover it would not be chargeable to the Patent Office, since this was an important interference and not a usual search case involving Patent Office personnel only. The final legal decision was by three Examiners-in-Chief, paper 67, January 27, 1922. Because of the importance of the matter, the papers then went before William A. Kirman, First Assistant Commissioner, so that both parties would have the informal views of even a higher official of the Patent

[28] Letter of Alexanderson to Hammond, October 21, 1912.

[29] Hammond to Lowenstein, October 24, 1912.

[30] Hammond to Lowenstein, October 23, 1912.

[31] Enclosures in letter of W. G. Gartner of the General Electric Company to Hammond, July 1, 1913.

[32] Brief for Heising, U. S. Patent Office Interference 43,858, Paper No. 64; October 21, 1912.

Office. On January 29, 1923, he wrote: "There is no appeal from this holding of the Examiners-in-Chief that Count 4 is patentable. . . . This patent to Scheller does not, in my judgement, disclose any 'means for selecting a component of said selected energy'. . . . The decision of the Examiners-in-Chief is affirmed." And on April 13, 1923, Mr. Kirman further wrote: "As to the allowance of the claim to the party Hammond, it may be allowed in any application in which it can be properly made." The case is finished, the Telephone Company bought rights under the Hammond patents, the patent numbers were put upon equipments, the patents have expired. It is rather late for a consultant of the Telephone Company to now suggest that the Patent Office overlooked such a well-known "Telefunken" art and that the Telephone Company bought patents that were invalid.

37) *Critique.* "Hammond cannot be credited with originating the double-detection technique, starting, as it did, with audio-frequency IF."

Rebuttal. Readers will be amazed to find someone who as of the present date will refer to an *audio-frequency intermediate frequency.*

38) *Critique.* "Of Alexanderson's 1912 tuned-radio-frequency circuit shown in Fig. 12. . . . "

Rebuttal. The caption of this figure does not justify this interpretation. The circuit shown originated with Alexanderson after his invention of TRF in Gloucester, and came to Hammond in a letter of October 21, 1912.[33] The word "later" in our paper should not be overlooked. For the purpose of showing the relations between the TRF system of Alexanderson and the IF system of Hammond, we were entitled to hypothesize the devices commonly termed "Audion detectors" or simply "detectors," either as actual detectors or as actual amplifiers.

39) *Critique.* "One reads: 'Fig. 82 illustrates a type of transmitter-receiver unit suggested by the writer in 1911."

Rebuttal. The implication of this statement is most readily refuted. Fig. 82 of the book cited corresponds almost exactly with two figures of U. S. Patent 1,491,773. That Hammond was the inventor of the patented material shown in this patent is evidenced by his signature at the end of the specifications. If our critic does not consider this sufficient, the fact that Miessner was not the inventor of the patented material is evidenced by his signature as a witness. Our critic presumably has failed to note an alleged relation between the receiver system of the figure cited and the TRF circuitry of Alexanderson, available in a reference[34] cited in our previous paper.

40) *Critique.* "Another claim for a 'first' must be corrected."

Rebuttal. In preparing our paper, we endeavored to leave out any reference to the word "Hammond" wherever we considered that there would be no misinterpretation as to the meaning. Most readers, we believe, made a mental insertion of the words *by Hammond* after "was first applied" in the cited passage.

41) *Critique.* "The apparatus is said to have been. . . . "

Rebuttal. Some may construe this method of expression to convey doubts on the part of the critic that the alleged equipment ever existed, or, if it existed, that it ever went to France. Our records show that on November 2, 1918, a conference was held at the Department of Development and Inspection,[35] Signal Corps, A.E.F., in France, to discuss this Hammond equipment with Messrs. Chaffee and Buswell of the Hammond Staff. Present were General Russel, Colonel Carty, Captain Armstrong, and Lieutenant Fahys. From published biographical material, it is most certain that Colonel Carty ("who during the whole interview was polite and cordial") was then also the chief engineer of the Telephone Company, and one with whom Hammond had had dealings in 1912 in the Lowenstein amplifier matter. Our critic undoubtedly can check with the records of the Telephone Company to settle his doubts in this matter.

42) *Critique.* " . . . the short wave multiplex radio telephone system developed by the Western Electric Company. . . . "

Comment. This is presumably the equipment upon which the party Heising properly wrote the patent claim which has been cited. If so, this equipment was later proven to be subservient to the prior Hammond art. The time lag between installation and publication is noted, but without surprise. Contemporary equipment upon which publication was also delayed included the Hammond IF system that had been previously used in control work, and that upon which construction was started in 1917 and which was delivered in Europe in 1918. The comparison between the merits of the Heising naval equipment and the Hammond military equipment is out of order. The Telephone Company work was in communication between ships; the Hammond work was in finding a military solution to such problems as avoiding the necessity of requiring U. S. Infantry to advance into its own Artillery barrage.

43) *Critique.* "Of course both detectors were 'of an oscillatory nature,' detection of oscillations being their function."

Rebuttal. This statement is improperly based upon a confused concept of an oscillatory detector. Crystal diode detectors were detectors of oscillations but they were not therefore oscillatory detectors. Although the first detector of the equipment under discussion was advisely used in the non-oscillatory condition for the proper reception from the corresponding military transmitter, it did often oscillate during the course of making adjustments. Under these conditions, the circuit most certainly had the structure of a CW "superheterodyne" regardless of whether or not there was any CW to be received. We fail to understand why our critic is disturbed by our remark upon this point, since the CW "superheterodyne" is an Alexanderson invention in whatever respects it is not a Hammond invention, as now to be recorded.

44) *Critique.* "The first to arrive at the true superheterodyne and apply for a patent upon it, was one Lucian Levy of Paris."

Rebuttal. This is in error. The French patent to Levy was filed August 4, 1917, and his U. S. Patent 1,734,038 was filed August 12, 1918, with an additional figure. This U. S. patent later received claims 1, 2, 3, 6, 7, 8, and 9 from the well-known Armstrong patent. These claims relate to the amplification of readily amplifiable intermediate frequencies in the telephonic-type superheterodyne. At the same time, and in the same manner, Armstrong claims 4 and 5 went to Alexanderson U. S. Patent 1,508,151, and claim 4 remained there as claim 20. This relates to the amplification of readily amplifiable intermediate frequencies in the CW-type superheterodyne. This U. S. patent was a divisional patent based upon disclosures that are also in a prior Alexanderson patent 1,465,961, filed April 19, 1916, over a year before the date of Levy's filing in France. This is the effective filing date of both the Alexanderson patents, and it takes precedence over Levy as to the general concept of amplifying a readily amplifiable IF in a superheterodyne. Before both Alexanderson and Levy, Hammond in 1912 had filed upon his U. S. 1,491,774 which specifically covers the telephonic-type superheterodyne structure, but of course without the addition of tuned amplification of superaudible frequencies which was a later Alexanderson contribution, also of 1912.

45) *Critique.* "Hammond's works were entirely unknown in France in 1917."

Rebuttal. This statement is in error. Hammond at that time had several patents pending in the French Patent Office. Radiodynamic patents 474,906 and 475,888 had been published in 1915; intermediate-frequency patent 519,811 was entered into the French Office on December 12, 1917, based upon U. S. Patent 1,491,775, filed September 28, 1916.

46) *Critique.* "Thus it is apparent that IF technology came into being and went into service quite independently of Hammond's more secret efforts in the field."

Rebuttal. This statement is not justifiable by the facts. That Hammond's efforts were not secret even from the pioneer in the commercialization of the superheterodyne, and that they had a very definite technological bearing is evident from the following incident. On November 8, 1918, Captain E. H. Armstrong requested the presence of Dr. E. L. Chaffee to explain a technical point as to the proper design of intermediate-frequency transformers. The desired information was freely given.

V. Frequency Modulation and Related Systems

47) *Critique.* "A Hammond patent is cited. . . ."

Rebuttal. Our critic apparently cannot think back to the period of the filing date of this patent, when receivers were very broadband, CW signal rates were twenty words per minute, and key shifts were 300 cycles. The patent certainly could be practiced without serious cross-signalling, just as can its modern television counterpart. There are other patents in the Hammond group, and other pertinent Hammond activities, that make the tie between the early patent and

[33] Alexanderson to Hammond, October 21, 1912.
[34] Authors' previous paper, footnote 32, p. 1198; see p. 1366 of the reference.
[35] Compare this address with that of p. 5 of the reference in the authors' previous paper, footnote 62.

modern color TV technique more close than would appear from our paper.

48) *Critique.* "The presentation of the Chaffee transmitter of Fig. 16 as a part of a 'noise reduction system' is misleading. . . . "

Rebuttal. The system undertook to reduce all noises coming into the receiver insofar as they produced equal effects in circuits tuned to the two ends of the spectrum. Hum reduction was cited as an obvious example. The system also reduces disturbances that are not so equally present in both ends of the spectrum. Our critic should check the nature of the spectrum shown with that of a sine-wave FM signal with a modulation index of 2.4 to see that the Chaffee system had the noise reduction merits of modern FM systems, except as to amplitude limiting.

49) *Critique.* "Appearing initially as a fault, the making of a virtue of this effect was a natural second thought."

Rebuttal. Knowledge of this effect even in the early broadcast brand of frequencies was the basis of the 1921 work of our junior author in developing the first all-electronic type of FM transmitter, with performance as indicated in Fig. 15.

50) *Critique.* "Chaffee of the Bell Telephone Laboratories thus sought to utilize it and devised a receiver for an FM system."

Comment. By the critic's footnote reference to the papers of J. G. Chaffee, this work was published in 1935. By that time, nearly all the really basic work in the field of FM had been completed and the important patents of the workers cited in our paper had come to issue. It is further believed that the Telephone Company was among those which had rights under the patents and the patent applications covering the Hammond Laboratory work in this field. If it had so desired, the Telephone Company could have made a good commercial beginning in the FM field on the basis of the Hammond patents alone.

General Comments

Our critic's attempts to downgrade the judgments of contemporary experts as to the value of Hammond's work are not the first. At least three prominent pioneers in radio-electronics advised the Government against taking its initial step in radio guidance of missiles. The acting Secretary of War,[4] in rebuttal advised Congress, in effect, that: Hammond's work was far advanced over the prior art, with a hundred patent applications and a thousand allowed claims; the patents of Rear Admiral Fiske which some claimed to be basic would expire in about sixteen months, so that there was little danger of trouble from the Western Electric owners; Hammond was holding the Government free from liability in case of infringement suits; and the actual risk was but $30,000 since the Government would not be obligated in case of an adverse report by the newly-to-be-created Board. The recommendations of the previous Army and Navy officers had been so favorable that Congress had no hesitation in proceeding. The value of the inventions, developments and patents had been affirmed by the legal departments of the Army and the Navy, and is most generally accepted by officers and others who have examined the facts. As to the field of intermediate-frequency circuitry, chief patent attorney George E. Folk of the Telephone Company conferred with Hammond even before the termination of the Heising interference, and acknowledged that Hammond was going to be the winner. Therefore he took steps to secure rights under the Hammond inventions and patents for the Telephone Company and further advised the Radio Corporation he thought it should do likewise. This action, coupled with the direct findings of the Radio Corporation and similar advices from others including E. H. Armstrong, resulted in the Hammond work becoming immediately available to the industry without any further litigation.

Conclusion

In conclusion, we deeply regret the necessity of having had to point out the many errors of simple facts on the part of our critic. We regret the necessity of having had to correct so many misinterpretations of our statements in the paper, on points that should not have disturbed him and others. We regret the necessity of having had to go into more personal matters, to show how the various developments appeared to others at the times at which they were being made. By failing to comment upon other matters than the fifty items here discussed, we do not wish to be considered negligent, if there are errors of fact in the extraneous material presented in the critique.

John Hays Hammond, Jr.
E. S. Purington
Hammond Research Corp.
Gloucester, Mass.

Replication of Rebuttal by Mr. Espenschied*

Of the fifty points of rebuttal, only a few need further attention:

3) Of the twin Fiske patents of 1900 on the wireless control of torpedoes, Nos. 660,155 and 660,156, Hammond in 1912 called one of them "the first" of its kind, when seeking information about it, as already noted. Subsequently he ignored Fiske, and now the authors reject him. In claiming Hammond did not infringe Fiske, there is quoted a claim, obviously broad, with the contention that the words with which it ends, "as set forth," limit its scope in some unspecified manner. This refusal to recognize a predecessor lends significance to certain additional information known to the writer which is now presented in justice to Admiral Fiske.

When in 1915–1916 Hammond was selling to a war-worried Uncle Sam his own project of a wireless-controlled torpedo—which never succeeded—Admiral Fiske became concerned lest his patents be infringed and wrote the company to which he had assigned them, the Western Electric Company. That company then had the matter studied by a college-professor patent attorney, P. I. Wold. On March 9, 1916, he reported to Western's Patent Counsel, D. C. Tanner, saying "we have made a study of the Fiske Patents and certain patents to Hammond, who is a possible infringing party." He concluded:

> . . . that the claims of the Fiske patents are valid, are not subsidiary to other patents and are basic in scope. His arrangement is operative. Hammond has a patent for a somewhat similar device but his claims are limited to his specific apparatus and are furthermore subsidiary to the Fiske claims. We are also unable to see, at present, how Hammond or others can make any devices of this nature without infringing Fiske's patents. Fiske's patents, however, expire in about 19 months and any steps, such as infringement warnings, should therefore be taken in the near future. In view of Court decisions on Government contracts it may be that Hammond or others will ignore these patents, in which case our only recourse will be to the Court of Claims.

On March 10, 1916, Tanner sent to his superior, Mr. Swope, a copy of the Wold report. He recommended against taking "any such action against the Government, . . . in view of our relations." He suggested the company offer to turn back to Admiral Fiske his two patents, "upon repayment by him of what they have cost us." They are not known to have been repossessed by Fiske. Probably he realized only too well the trials and expense of a lengthy law suit. He is not known to have gained anything from his imaginative and patriotic endeavor; and now we see him denied even recognition. Such is hardly objective technical history!

6) Three statements in the original paper gave the impression that Hammond claimed to have developed, in 1910–1914, the principles of automatic course stabilization by means of the gyro:

> Many developments by the Hammond Laboratory established basic principles used in modern airborne guided missiles, including the stabilization principle. . . . (Summary of paper.)
>
> Preliminary work by Hammond . . . resulted in the development of the automatic course stabilization principle . . . (p. 1192, column 1, lines 27–30).
>
> Automatic Course Stabilization. . . . The first navigational application of this automatic pilot principle was to the third boat, the *Natalia* of Fig. 2; the system was first put into long period operation on March 25, 1914. . . . (P. 1192, column 2, lines 34–38.)

Surely these claims give that impression. But all is well, now that the authors deny such intention.

12) The insistence of the authors that Hammond, and not Sperry, was the true pioneer in the development of the "automatic pilot," goes quite against the writer's impression, and doubtless of many others, but he will not further press the point, leaving it to others better qualified to judge. Perhaps the Sperry people will have something to say. Here is a good example of the many versions one can have of a certain technological origin, depending upon the viewpoint.

15) Hammond U. S. Patent 2,060,198 describes a torpedo in water and electromechanical means for communicating by compression waves with the object to be detected. In the absence of the disclosure of another medium and corresponding communication means, the term torpedo in the claims is to be construed in its ordinary meaning of a waterborne body. Hence, the attempt at making the claim read on the radio-controlled proximity fuse by calling the action the "Proximity" principle, is misleading.

* Received by the IRE, November 3, 1958.

16), 17), and 18) Robert Marriott's statement concerning the early use of the Audion, namely that:

> This form of detector was used to some extent as early as 1906.

is quite correct if it is understood what "this form of detector" was as of 1906. It was the diode, or two-element form, with "B" battery added by de Forest, as described in his 1906 AIEE paper entitled "The Audion." Marriott was well aware of this, the first, form of Audion, and was not limiting himself to the subsequent form, the grid triode, which later "stole the show." It was the authors, Hammond and Purington, who so limited him, by inserting, in connection with his statement, the words "three-electrode form of detector." Thereby Marriott's statement was altered, making the use of the grid Audion appear somewhat earlier than was the case. A small point, but one worth keeping straight historically.

The grid Audion was invented in the winter of 1906–1907. It began to be "used to some extent" not until 1907 to the writer's knowledge. The first public disclosure of it was by de Forest himself in his Brooklyn lecture on "Wireless" of March 14, 1907, already mentioned. The patent for the grid Audion was applied for January 29, 1907. It issued February 18, 1908 (not 1907 as previously stated by the present writer, an error he is glad to have corrected)—No. 879,532.

22) The authors appear not to have understood the comment. Fritz Lowenstein, employing de Forest's grid Audion, but wishing another name for his own purposes, called it an "ion controller"—much as had de Forest re-christened the Fleming Valve, to which he added a plate voltage, calling it "The Audion" as per his 1906 AIEE paper. How interleaving are inventions, but how reticent inventors to admit it!

29) The present writer mentioned several steps taken by Dr. H. D. Arnold in the telephone company's laboratory in attaining higher vacuum and generally improving de Forest's grid Audion, one of them being the importing of the latest kind of vacuum pump, the Gaede molecular, received in April, 1913. From this date, the authors assert " . . . the Telephone Company work was much later than that of the General Electric Company in the production of high-vacuum tubes." Quite the opposite was the conclusion of the Supreme Court of the United States in the famous Arnold-Langmuir litigation over the high-vacuum tube, where the telephone company's priority was recognized in these words:

> August 20, 1912, the earliest date claimed for Langmuir was rejected rightly, we think, by the district court, which held that Langmuir was anticipated by Arnold in November, 1912.[1]

The high-vacuum tube, in its use in transmitting as well as receiving, over wires as well as by radio, proved to be second only to the grid Audion itself as a cornerstone of modern radio-electronics.

[1] The decision, handed down May 25, 1931, recognized also that de Forest himself had gone part way to high-vacuum, without fully knowing what he was doing. Published in "Cases Argued and Decided in the Supreme Court of the United States," Book 75, Lawyers Edition, 1931. De Forest Radio Co., Petitioner, vs General Electric Co., No. 660.

Finally, a personal note. The writer's discussion of the Hammond-Purington paper has been offered to balance its excessive claims, in the interest of more correct technical history. The writer is not a spokesman for the telephone company, has not consulted the company, from which he has been retired some years. He has merely used knowledge that came to him in a long active career in the field.

Comments on "Replication of Rebuttal" by Mr. Hammond and Mr. Purington*

At the outset, we wish to thank our critic for making clear to all what we had long since sensed, that his "Critique" of our September, 1957 paper in the PROC. IRE was not reviewed by an executive of the Telephone Company. We are pleased that we must proceed further with only nine of the fifty items which we discussed in our first response. Our final comments follow.

3) *The Fiske Patents:* In our files, the only statement by Admiral Fiske concerning these patents is that made in the high-policy conference of February 9, 1916, (our rebuttal reference 9a, p. 35 of the report): "Rear Admiral Fiske: I suppose you understand that I am not an unbiased witness. I want that understood. I invented this general scheme in 1897 and got a patent on it, and the patent has not expired. It is a basic patent. I want that understood." There was no mention of any reduction to practice either by Fiske or by the Western Electric Company. Our interpretation of the word "as" in the phrase "as set forth" is the dictionary meaning "in the same manner." We feel no patent lawyer would accept a claim with the words "as set forth" at the end of an otherwise basic claim unless by compulsion. We did not quote the Fiske claim, but a very similar Tesla claim. By the words " . . . our only recourse . . . " in the Wold report to Tanner, it would appear that Prof. P. I. Wold was more closely related to the Western Electric Company than our critic would like his readers to believe. Upon continued study of the patents after his inquiry concerning them cited by our critic, Hammond found design errors which experts believed rendered the structures inoperative. Even after the Tanner recommendation not to take action against the Government, the possibility of such action was called to the attention of the Government by another and presumably disinterested engineer, to which Hammond responded by guaranteeing to hold the Government harmless in case of any and all patent difficulties. In a paper covering contributions to technology, it would have been improper to refer to one as a pioneer whose inventive effort was not reduced to practice by himself or by others as his agents. Please note, however, that in rebutting our critic in this matter, we do not wish to create the impression that we do not have great admiration for the extensive pioneering work of Fiske in other fields of naval development.

" . . . which never succeeded . . . " is a complete misstatement of fact. The Hammond torpedo-control system tested by the Navy at the Newport Torpedo Station fulfilled the exacting requirements of the Chief of Naval Ordnance, and the report of these successful demonstrations was given by Admiral Leahy to the Secretary of the Navy. The non-use of the device was due to naval policy and this was formulated upon the problem of mass production for war and difficulties encountered with the new magnetic detonators. The Hammond control system was widely used in the control of naval targets, and the Hammond-Sperry inventions created the target "drones" and finally the basic control of modern missiles.

6) *Developments of 1910–1914:* The sentences which gave our critic trouble will, we believe, not confuse those who take the adjacent sentences and paragraph headings into consideration.

12) *The Automatic Pilot:* Others better qualified to judge will first consider the meaning of the word combination "automatic pilot." Then we are confident that they will not have difficulty in differentiating between the contributions of Sperry and of Hammond to the navigational art.

15) *The Proximity Principle:* Patents are written to be read and understood by experts. The terms used are to be interpreted as broadly as expert usage will permit. As regards this patent, the expert usage had been established for more than a decade. Thus, during the conference of a distinguished group of high officers with Hammond at Fort Monroe, August 23, 1918, the following was officially recorded. (Emphasis is by us.)

"General Squier: You have shown this afternoon the control of the *regular torpedo in water* both by the *radio device* and also by *acoustics*. Why do you limit yourself to water? Why don't you get an *aerial torpedo?*

"Mr. Hammond: I have covered that entirely from the standpoint of patents. The reason that I have not given it more thought is that I am specifically attacking the underwater section of capital ships. . . . I have not made any experiments; I have merely concentrated on this proposition for the Coast Artillery.

"General Squier: Is the *aerial torpedo* a harder problem?

"Mr. Hammond: It is harder to my mind."

Note that in a single paragraph, the Chief Signal Officer of World War I referred to two kinds of torpedoes and to two kinds of energy by which they may be controlled. Clearly the examiner of the proximity patent years later would have required Hammond to insert *underwater* before "torpedo" and *acoustic* before "energy," if he had intended to restrict the scope of the patent to the form set forth. It is inconsistent for our critic to assert that the Fiske claim terminating with the words "as set forth" is basic to the radio-control principle in forms not shown, and yet to deny that the Hammond claim cited in our paper is not basic to the proximity principle generally, with the words "as set forth" absent. In contrast with

* Received by the IRE, May 13, 1959.

the Fiske radio-control patent, the Hammond proximity patent did get reduced to practice, we understand, in both media. It was not generally known, presumably because no money passed in making it available, and there was no threat of a law suit.

16), 17), and 18). *The deForest Audion:* We feel that there is need for a formal syllogism:

Major Premise: In writing the words "Audion. This form of detector . . . ," Marriott had in mind only one form of detector, since he used the word "this."

Minor Premise: The form to which he referred as being used in 1912 was unquestionably the triode.

Conclusion: The form to which he referred as being used in 1906 was therefore the triode.

Our critic is charging that Marriott was in error or that he did not express himself clearly. Since the patent application was signed in 1906, no one has the right to assume that the inventor did not practice his invention in 1906. The fact that it was not publicly disclosed until 1907 is irrelevant. Strangely, it is we who have to defend an author and his paper, when both were praised by our critic when the paper was first published.

As to the date of the patent, we corrected this formally and not by letter to the critic, because of the criticism, expressed by the exclamation point, that the Patent Office may have failed to consider it for a sufficient period of time. As far as we have observed, one would have to go back to the original Bell patent of 1876 to find an important patent which was issued after only three weeks of consideration.

22) *The Lowenstein Designation "Ion Controller":* We believe we understood the comment as written. An "alias" connotes another name without change of the object named. Lowenstein's device was a triode, and most certainly not an "audion" comprising a diode in series with a B battery, which is the only type of "audion" mentioned in the sentence. We doubt that Lowenstein's reasons for using "ion-controller" rather than "grid audion" were unethical. The word "audion" automatically signifies a detector in the patent and technical literature. Such a terminology was not sufficiently general for one with the superior knowledge that a triode was also useful for amplification and oscillation uses.

29) *Priority of Production of a High-Vacuum Tube.* Our critic finally invokes a 1931 statement of the Supreme Court in its termination of a General Electric suit against the de Forest company for alleged infringement of Langmuir's high vacuum patent 1,558,436 of 1925. This seemingly self-contradicting sentence was lifted from pertinent context, but upon consulting acceptable reports of all three courts involved, we have paraphrased the final decision as follows. "We do not question that Langmuir and Sweetser produced a 250 v, 5 ma high vacuum tube 'in which the current was limited by space charge, substantially independently of positive ionization,' in August, 1912. But by legal precedent we think that his legal date of conception of the patent claims based upon this work cannot be the date that he did it but rather the date that he knew that he had done it. We rule that Langmuir's legal date of conception was in late November of 1912. We further rule that Arnold's legal date of conception was November 14, 1912, despite de Forest's strange willingness to accept November 1. Therefore in November, 1912, Arnold anticipated Langmuir by about a week in conceiving the subject matter of the Langmuir claims. But the Federal Telegraph Company used a 54 volt amplifying triode in August, 1912, and a 67½ volt triode in November, thereby anticipating both Arnold's and Langmuir's legal dates of conception. Partly upon this Federal evidence, the Langmuir patent is hereby and irrevocably declared invalid and therefore not infringed. We feel it highly unnecessary to rule on the prior statement that Arnold's reduction to practice of the Langmuir claims was on April 25, 1913." If our interpretation of the Supreme Court decision is acceptable, our critic must agree that the Telephone Company work was much later than that of the General Electric in the production of high vacuum tubes.

In conclusion, it appears that our critic refused further comment on about eighty per cent of the points listed in our first rebuttal. We trust that he would refuse further comment on at least eighty per cent of the points treated again in this second response to his critiques. We note that his discussions have been offered "in the interest of more correct technical history." We hope the four papers of these discussions have done much to confirm the correctness of the technical history which we set forth in our September, 1957 paper.

Correspondence

Low-Noise Tunnel-Diode Amplifier*

Since Hull first disclosed the dynatron,[1] negative conductance amplifiers have received sporadic attention. As early in 1935, E. W. Herold pointed out the possibility of using negative conductance for amplification.[2] However, lack of convenient negative-conductance elements made such amplifiers unattractive. The purpose of this note is to report some results on a new negative-conductance amplifier using a novel semiconductor device called a tunnel diode[3] which was developed by H. S. Sommers at the RCA Laboratories.

The amplifier circuit is shown in Fig. 1. The tunnel diode D, having a capacitance C_d, is energized by a battery V_0 through a dc load resistance r_0. The resistance r_0 should be smaller than the negative resistance produced so that stable biasing is possible. The biasing point at which the negative conductance is realized is defined by the combined adjustment of the load resistance r_0 and the supply V_0. As shown in Fig. 1, the negative conductance is shunted by an RF tank which determines the amplifier resonant frequency f_1. C_b, a by-pass condense in the tank, should be made as large a possible to prevent parasitic oscillations in the battery circuit. For stability, the RF load conductance presented by the combination of the generator conductance G_g and load conductance G_L through a tap transformation should be larger than the negative conductance (G) of the diode. Stable amplification can be achieved only when both dc and RF load conditions are fulfilled.

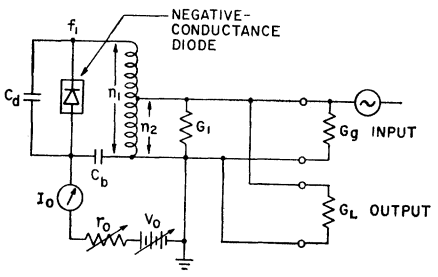

Fig. 1—Amplifier circuit using a negative-conductance diode.

Expressions for power gain (g_p), bandwidth (Δf), and noise factor (F) of Fig. 1 have been calculated; they are

$$g_p = \frac{4G_gG_L}{\left(G_T - \left(\frac{n_1}{n_2}\right)^2 G\right)^2} \tag{1}$$

$$B = \frac{1}{Q_L\sqrt{g_p}}\left[1 + \sqrt{1 + 4Q_L^2 g_p}\right] - 2$$

$$\cong \frac{1}{Q_L\sqrt{g_p}}\left[1 + \frac{1}{4Q_L\sqrt{g_p}}\right] \quad (\text{if } Q_L\sqrt{g_p} \gg 1) \tag{2}$$

* Received by the IRE, May 1, 1959. This research was sponsored in part by the Electronic Res. Directorate, AF Cambridge Res. Center, under Contract AF19-(604)-4980.

[1] A. W. Hull "Description of the dynatron," PROC. IRE, vol. 6, p. 5; February 1918.

[2] E. W. Herold "Negative resistance and devices for obtaining it," PROC. IRE, vol. 23, p. 1201; October, 1935.

[3] H. S. Sommers, "Tunnel diodes as high frequency devices," PROC. IRE, (this issue, p. 1201).