

**Mendell Penco Weinbach
and the
K&E Log Log Vector Slide Rules**

By William K. Robinson

Mendell Penco Weinbach and the K&E Log Log Vector Slide Rules
By William K. Robinson

This article is about Professor Mendell Penco Weinbach and his contributions to the development of the two K&E Log Log Vector Slide Rules. These were the Log Log Vector Slide Rule, K&E 4093, introduced in late 1929; and the Log Log Duplex Vector Slide Rule, K&E 4083, following ten years later in 1939.

The introduction of the K&E 4093 Log Log Vector slide rule with hyperbolic scales should be considered an important milestone in slide rule history. This is not for the fact that, for the first time, one could read the values of the hyperbolic functions on a slide rule, but for the fact that one could now calculate the values of the complex hyperbolic functions. This new slide rule provided rapid and direct solutions for expressions such as $\sinh (u + j \theta) = A e^{j\theta} = A / \alpha$, in the Vector form; or, $\sinh (u + j \theta) = (x + j y)$, in the Cartesian form. These complex hyperbolic functions were being encountered more and more often in the fast growing scientific and electrical engineering applications of the time.

Weinbach's slide rule design gave the scientist and engineer an immensely valuable and timesaving tool. Its importance for them really cannot be overstated. In fact, in late February 1928, Professor A. E. Kennelly, of Harvard University, one of the leading Electrical Engineers of that time, had this to say about a sample of the slide rule that Weinbach had sent to him, "This rule has, as you point out, two main utilities; first, the conversion of polar to rectangular complex quantities and reciprocally; second, the computation of $\sinh (u + j \theta)$, $\cosh (u + j \theta)$, and $\tanh (u + j \theta)$, either in rectangular or polar forms, but especially in polars. Of course the first utility is not new as there are some slide rules on the market which will enable this utility to be obtained. This is, however, the first slide rule, to my knowledge, to provide the second utility, and certainly the first thereof to provide both utilities combined. I think it should give valuable service to electrical engineers employing complex numbers and complex angles as many of us do now. I congratulate you on achieving this possibility".

Kennelly was right about Weinbach's design. Prior to the advent of this slide rule these complex hyperbolic equations were handled by a lengthy hand calculation routine using logarithms. In Appendix 1, following this Article, are examples showing the hand calculation method using logarithms, and those using the K&E 4093 and 4083 slide rules. When the difficult hand calculation steps are compared to the much easier and faster solutions by the slide rules there is no question of which method is superior.

The narration that follows covers eighteen years. It begins on a promising note in 1928, and sadly culminates in 1946 with litigation. It covers the history of Professor Weinbach's relations with Keuffel & Esser Co. During this period of time four distinct phases occurred. These were:

Phase one, 1928-1930: During this time Weinbach performed the major role in the design and evolution of the Log Log Vector Slide Rule, the K&E 4093.

Phase two, 1933-1935: It was in this period that Weinbach had a number of exchanges with K&E regarding concerns about royalties.

Phase three, 1938-1939: This reviews Weinbach's part in K&E's introduction of the Log Log Duplex Vector Slide Rule, K&E 4083.

Phase four, 1944-1946: Weinbach initiates litigation against K&E.

First, in this Article, we will learn a few things about Professor Weinbach's life, and then go on to recount the events in the four Phases. The source of information for most of this Article is from the Archives of the University of Missouri at Columbia where they have a collection of the professional papers of the Professor. These were donated to the University in March 2004 by his family. In May 2007 I visited the University, and with the assistance of the Archives Staff, and my daughter, Kathryn, gathered copies of about 400 pages of correspondence and material. Then, during the drafting of this Article an additional 260 pages of material covering Phase four was discovered by Richard Kershenbaum, his grandson. These papers were also donated to the Archives, and I was able to make copies of them. The Archives records are remarkably complete and show the entire history of the important events that transpired over the eighteen years; 1928-1946.

Most of what follows in this Article is information that I have copied, summarized, and/or condensed from these Archive papers. Where wording is copied directly it is noted by quotation marks (""). Other wording, summarized from the papers by the Author, is not noted by quotation marks. It should be mentioned that when copying direct quotations I recorded them as originally written and no attempt was made to correct their spelling or grammar. Often shown are sequences of multiple quotations that have been taken from different places in the same letter. When this occurs quotations marks ("") have been shown at the beginning and end of each quote, and a new paragraph indentation begins with each quote. However, there is no line spacing between these multiple quotation paragraphs. In all the rest of this Article regular line spacing and paragraph indentation is used.

This may be the first time in the history of slide rules that the complete records of correspondence between the manufacturer and an independent designer of a slide rule have been preserved. These allow us to obtain a rare picture showing the human and business aspects of the development of two slide rules from inception to introduction to the public. From these pages there emerges a fascinating story of Professor Weinbach and his long term relations with K&E. This Article is lengthy. However, I have purposely included as much documentation and detail from the Archives as was considered necessary to complete this unique and historical record of events.

The biographical information that follows came from the "Archives" website:

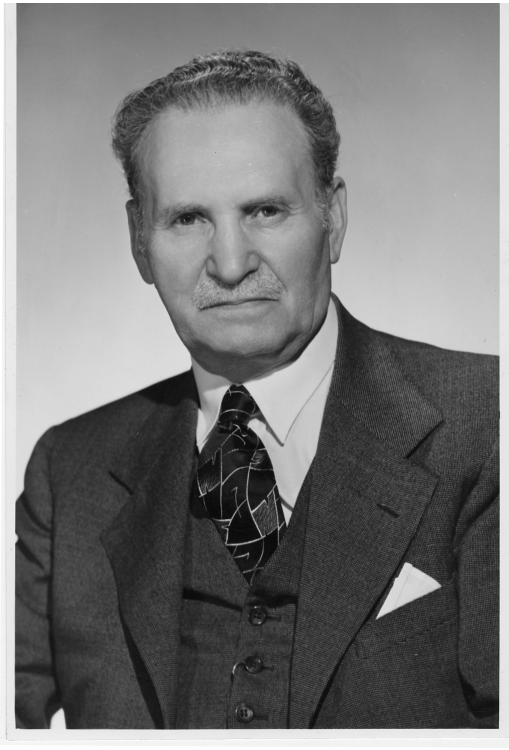
"Mendell Penco Weinbach was born on 2 November 1881 in Romania. He studied at the Romanian Lyceum before immigrating to the United States in 1901 at the age of 20. He received A.B. (1905), B.S. (1907) and A.M. (1907) degrees from the University of Missouri specializing in mathematics and engineering. Weinbach taught physics at the University High School while pursuing his education in engineering and joined the faculty of the Department of Engineering as an instructor in electrical engineering in

1907 and eventually became a full professor in 1923. He was chairman of the Department of Electrical Engineering in the College of Engineering for the last twenty years of his life. In the late 1920s Weinbach worked for AT&T in New York and Kansas City Power and Light during the summers. During WWII, Weinbach authored instructional materials and taught courses to students at the University of Missouri who were studying to be aircraft radio operators in the US Army Air Corps.

Professor Weinbach invented a number of devices and held several patents. His most successful invention was the Log Log Vector™ Slide Rule that made mathematical computations easier for electrical engineers. The slide rule was a great success but it was also the focus of a long legal dispute with the company which marketed it, Keuffel & Esser Co (K&E), over royalties and breach of contract. Weinbach also wrote a number of well received textbooks for electrical engineering students and was engaged in several publishing projects when he unexpectedly died after a short illness on 29 March 1947. Weinbach and his wife Regina Paves Weinbach (d. 1945) raised five children in Columbia, MO.

This collection of papers created by M.P. Weinbach was kept after his death by his daughters, Edith Weinbach and Charlotte Weinbach Kershenbaum. Professor Weinbach's grandson, Richard Kershenbaum, donated the papers to the University of Missouri-Columbia Archives in March of 2004. The heirs of Professor Weinbach earlier donated the large prototypes of the Log Log Vector™ Slide Rule to the College of Engineering for their museum. As of 2004, the prototype slide rule is still on display in the MU College of Engineering.”

This picture of Professor Weinbach, Chairman of the Department of Electrical Engineering, was taken in May 1946 when he was 65 years old.



Phase one: 1928-1930: The introduction of the K&E Log Log Vector Slide Rule; the K&E 4093

Our story begins on March 7, 1928. On this day Professor Weinbach submitted an application for a copyright on the design of a slide rule with decimally divided trigonometric and hyperbolic scales. This was registered under U. S. Copyright Class I XXC No. 15998. This slide rule was pictured in a paper titled “Vector Calculating Devices” that he was about to present at the Regional Meeting of the *American Institute of Electrical Engineers (A.I.E.E.)* in St. Louis, Mo., March 7-9 (See Figure 1). He called it the “Vector Slide Rule”, and described its operation. The article gave examples of how the scales could be used. These covered not only the usual slide rule and vector calculations, but also the hyperbolic functions, and solutions of complex hyperbolic forms such as $\sinh(u + j\theta)$, $\cosh(u + j\theta)$, and $\tanh(u + j\theta)$.

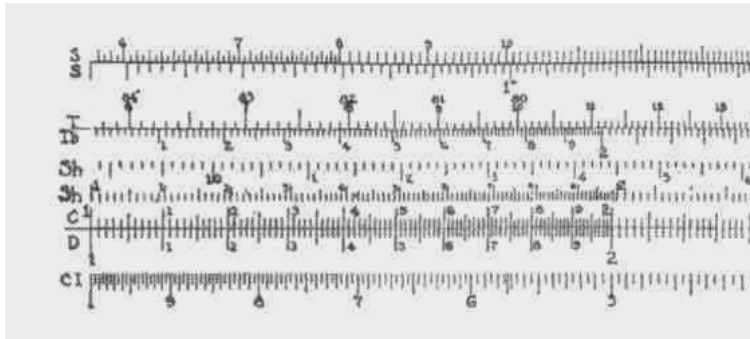


Figure 1.

Just one side of the Vector slide rule was pictured in his paper, and it had the following nine scales on it, from top to bottom:

1. S (for sines from 5.7 – 90 degrees);
2. S (for sines from 0.7 – 5.7 degrees);
3. T (for tangents from 5.7 – 45 degrees, and cotangents larger than 45 degrees);
4. Th (for hyperbolic tangents from 0.1 – 3.0 radians);
5. Sh (for hyperbolic sines from 0.1 – 1.0 radians);
6. Sh (for hyperbolic sines from 1.0 – 3.0 radians);
7. C (a standard C scale);
8. D (a standard D scale);
9. CI (a standard CI scale that could also be used for tangents larger than 45 degrees, and cotangents less than 45 degrees).

Scales S, S and T were to be read on the D scale; Th, Sh, and Sh were to be read on the C scale; and CI was to be read on the T scale. A most important new feature of Weinbach’s design was that the S, S, and T scales were in decimal degrees, and not the customary degrees and minutes. The introduction of decimal degrees was a major improvement.

The paper received an immediate positive response from fellow engineers and he was advised by them to have a reliable manufacturer make his rule available to the profession.

So a few days later on March 13, 1928 he sent a letter to K&E with a copy of his paper. It was his hope K&E would have some interest in producing his slide rule.

On March 22, 1928, W. G. Keuffel, President of K&E, replied with a flat turn down. He thanked Weinbach for a copy of the paper, but said the idea of a slide rule to be used for Vector calculations was not new to them. In fact, about five years before they had actually made a slide rule for electrical research and had submitted copies of it to different parties, but could find no real demand for it. K&E enclosed a copy of the directions that they had sent out with the rules they had furnished. Also, they asked if Weinbach was aware of Patent No. 1,487,085 that had been issued on May, 25 1924 to Albert F. Puchstein. (Author's insert: Puchstein was a Professor of Electrical Engineering at Ohio State University. His Patent was titled: "*Device for Making Vector Calculations*". His slide rule, as pictured on the Patent pages, had scales with hyperbolic functions. In describing the rule Puchstein says; "*.....my device is of such a nature that calculations can be readily made as to hyperbolic sines, cosines, tangents, etcetera, of vectors*". Upon examination I found there was no comparison between the layout of scales on Weinbach's and Puchstein's rules. It is immediately obvious they are two separate and different designs. In fact, they were developed completely independent of each other as Weinbach had no prior knowledge of Puchstein's Patent).

Weinbach did not immediately reply to K&E's 3/22 letter. However, it did not seem to dissuade him as, in the interim, he arranged to meet with them when in New York in June. He was working there for the summer for American Telephone and Telegraph. He met with the officials, including the President, W. G. Keuffel, at their main office in Hoboken, New Jersey. He pointed out the favorable reaction of the profession following the publication of his paper in the A.I.E.E. Journal, and made an attempt to explain the important features of his slide rule with decimally divided scales. Also, he compared the scales on his rule to their unsuccessful "Electrical Research" one. This rule did not have hyperbolic scales. Again, the response from K&E was negative. President Keuffel indicated that their investigation showed there would not be enough demand to warrant manufacture. Also, he mentioned that they felt the patent by Puchstein was quite similar to his design.

Weinbach continued to persist and in late August 1928, before his return to the University of Missouri, he arranged another meeting with K&E. At this time he made another attempt to interest them in the manufacture of his slide rule. Again, he gave the advantages of his slide rule over other designs. In the interim period between meetings with them he had studied the Puchstein Patent and did not find the rules similar. So, at this meeting he was able to discuss the differences between the scales and operation of Puchstein's and his slide rule. Weinbach explained that although Puchstein did cover the evaluation of hyperbolic functions of complex variables there was an important difference in the essential details between the operations of the scales on the two rules. Weinbach further pointed out to them that the decimally divided trigonometric scales of his slide rule would eliminate the usual conversion errors resulting from the degree-minute scales on their "Electrical Research", Puchstein's, and other similarly designed rules. (Author's insert: The differences lay in the layout of the scales. Puchstein's Patent design only provided direct solutions of the complex hyperbolic functions in the complex vector form $(x + j y)$. On the other hand, Weinbach's Copyright design provided direct

solutions of the complex hyperbolic functions in the complex polar form $A/\alpha = A e^{j\theta}$. The basic mathematical formulas for the two methods are different and the slide rule procedures are not the same. Weinbach's design would have been preferred by electrical engineers, as solutions in the polar form are of great convenience to use when multiplying and dividing these complex numbers).

Finally, late in their discussion, after learning Weinbach had obtained a Copyright on his rule, President Keuffel had a change of mind. He said they might consider the manufacture of a vector slide rule. However, it would have to cover the use by K&E of both Puchstein's Patent and Weinbach's Copyright. The object he was told was that their Company, through this acquisition, would have complete ownership of the slide rule methods for these calculations. If sold, they would agree to pay a Royalty of 5% of the retail price. Also, Weinbach was to write an instruction book for the use of the rule in solving engineering problems. As the next step they asked Weinbach to consult with Professor Puchstein, at Ohio State University, to obtain his permission to use his Patent.

Weinbach contacted him and on August 30, 1928 the two Professors met at Puchstein's office at Ohio State. Weinbach's notes of the meeting are as follows:

"I informed Puchstein of my conferences with the K&E officials and that President Keuffel had intimated that they might manufacture a vector slide rule and test out the possible demand for it. That in such a case they want to have the complete protection offered by his Patent and my Copyright for which they are willing to pay a joint royalty of 5 per-cent of the retail price. Since Mr. Keuffel did not commit himself as to which scales were to be used, it was desirable that we come to some understanding regarding the division of the offered royalty. The agreement reached at the suggestion of Mr. Puchstein was that the one whose scales will be used shall receive 80% of the royalties. The drawing up of the agreement was left with Mr. Puchstein."

Following this meeting Puchstein sent Weinbach a letter confirming his understanding of the marketing agreement they had reached regarding the 80%-20% royalty division. Weinbach responded with an identical letter. Both letters were signed by witnesses to their signatures and contained this statement; "It is understood that the reason for this arrangement is, that so far as known, the Patent of A. F. Puchstein, and the Copyright of M. P. Weinbach constitute the pioneer efforts to devise suitable slide rule scales to accomplish said objects, and that this agreement is deemed best for the interests of both parties". Copies of the signed agreements "regarding the Vector slide rule" were sent by Weinbach to K&E on September 27, 1928.

It would take another year of correspondence between the three parties before the rule was finalized and ready for sale. During that time the negotiations regarding their agreement with K&E were completed. Also, the final layout of the scales on both sides of the slide rule was decided, and Weinbach finished the instruction manual. During this time, some "Test" rules were made to check the best arrangements of the scales. (Author's insert: During the writing of this Article, I was in contact with, Richard Kershenbaum, who is Professor Weinbach's grandson. He had found a slide rule in some of the Professor's belongings, and wondered if it could be identified. Below is a picture of this rule. It is one of the "Test" rules. Notice that this is a cut-and-paste job. It is simply a rearrangement of the scales of the slide rule pictured above in Weinbach's paper titled "Vector Calculating Devices". Someone made a copy of the slide rule picture, cut it

up, rearranged the scales, and then pasted them on this “Test” rule, see Figure 2. On this version all of the scales are included except for the C scale).

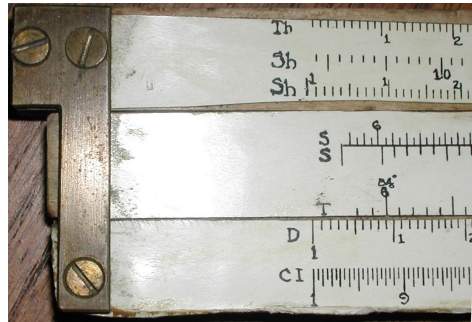


Figure 2.

Continuing with this Article, the letters written between the parties during the next year now follow. These are presented in date order to show how the slide rule was gradually developed.

Dec. 14, 1928; W. G. Keuffel to M.P.W. – In his letter W.G.K said that K&E had considered the construction of the rule suggested by Weinbach, and enclosed a blueprint of their idea of the arrangement of the scales on the Vector slide rule. In order to determine the best arrangement K&E said they would make a number of different rules to try out. Weinbach, in separate written notes said, “I noted that the hyperbolic and trigonometric scales as originally laid out by myself were interchanged on the blueprint. This, however, did not matter in the actual application of the scales.” Also, he noted the trigonometric scales had been inverted. Unfortunately no copy of this blueprint was found in the Archives. However, from subsequent correspondence that refers to the scales, a complete picture of the Front and Back of the rule on the blueprint can be created. The scales on what is referred to as the “general side” looked like this:

|| L, LL0, DF || CF, B, CI, C || D, LL3, LL2 ||

The scales on the “hyperbolic” side had been simply rearranged from Weinbach’s original design, except that his CI scale had been moved to the other side, and S and T scales had been added as follows:

|| Sh₁, Sh₂, Th || SI₁, SI₂, TI || D, S, T ||

We will find that, as time went by during the year 1929, Weinbach, Puchstein, and others suggested changes by adding other scales and features to the rule.

Dec. 17, 1928; M.P.W. to A.F.P. – M.P.W.’s letter updates Puchstein on his discussions with K&E over the past 2 ½ months, and sends him a copy of the blueprint sent by K&E. In this letter Weinbach says this about the slide rule;

“My aim with them was that they produce a slide rule that would not be restricted to only vector operations, but a general utility rule, that is a rule that in addition to vector operations including hyperbolics, would have as many other scales as could be put on it so as to insure its general utility character and consequently enhance its sales. The reason I held out for this type of rule was because of the small royalty offer, which coupled with the more or less restricted sales of a strictly vector slide rule would have made our efforts not worth financially. The rule that we have finally decided upon is shown in the blue print which I enclose. It is practically as I

suggested with the exception that the trigonometric scales are inverted as recommended by one of the K&E engineers.”

Weinbach asks Puchstein to return the blueprint with any suggestions he deems desirable. Then, as K&E will be using his slide rule design, he asks A.F.P. to send him a legally signed statement to the effect that M.P.W. will receive 4% (80%), and A.F.P. will receive 1% (20%) as Royalties.

Dec. 21, 1928; A.F.P. to M.P.W. – A.F.P. is having an attorney prepare the legal statement along the lines M.P.W. suggested. A.F.P. agrees that, “the idea of making the rule as much a general purpose rule as possible, is a good one. It is desirable to retain as many of the usual scales as possible, so long as the device does not become too large, too complicated, or too costly.”

Jan. 3, 1929; A.F.P. to M.P.W. – A.F.P. sends three copies of the legally signed statement to Weinbach per the Dec. 17, 1928 letter.

Jan. 5, 1929; M.P.W. to W.G. Keuffel – M.P.W. agrees that K&E should make a few sample rules for try out before the final arrangement of scales is decided upon. He advises K&E to add a CI scale on the back face. Also, a gauge mark of $180/\pi = 57.3$ should be added to the C and D scales on the front face. Referring to the division of royalties he says that Professor Puchstein and he had agreed royalties be apportioned to 20% for Professor Puchstein and 80% to him. They could confirm this with Professor Puchstein if they so desire.

Jan. 29, 1929; W.G. Keuffel to M.P.W. – W.G.K. again suggests that they make a few slide rules as shown in the blueprint dated December 14, 1928. In regard to the CI scale, he stated that, there would not be room to place another scale on that side. To read results the CI scale on the front can be used in conjunction with the duplex indicator to find the value on scales on the back face of the rule. M.P.W.’s suggestion about adding the 57.3 gauge mark on the C and D scales will be done. Let K&E know if it is agreeable to him if they proceed as outlined. Their technical office requests that he send them a copy of Hedrick’s book, “*Tables of Hyperbolic Functions*”.

Feb. 5, 1929; M.P.W. to W.G. Keuffel - M.P.W. again agrees that K&E should make a few sample rules for try out by Professor Puchstein, his students, and himself. He reminds K&E that last summer he gave them a copy of Hedrick’s book, “*Macmillan’s Logarithmic and Trigonometric Tables*.”

Feb. 5, 1929; M.P.W. to A.F.P. – M.P.W. enclosed a copy of the 1/29 K&E letter saying to A.F.P. that it will tell you the progress of our slide rule up to the present time. M.P.W. said that he had written K&E about their joint agreement, and referred K&E to A.F.P. for confirmation of it. Had they contacted him yet? M.P.W. has not drawn up any legal agreement with them, but they have agreed to the five percent royalty. If A.F.P. has any suggestions for the good of the matter they will be appreciated.

Feb. 11, 1929; A.F.P. to M.P.W. – A.F.P. had not yet heard from K&E, and said, “Presumably it is not highly important that they should write to me at present”. (Author’s insert: It is obvious that by now Professor Puchstein realizes he has a minor role in the development of the rule. Also, later in this Article we will find that he had been in contact with K&E a few years before and because of this did not have a high regard for the

Company). Referring to the hyperbolic functions he says, "I am again surprised to find their technical department as helpless as their letter states." He further said, "I have no suggestions except to repeat the general one that the rule contains the proper scales to make it useful for every day calculations of the electrical engineer....both real and complex."

Feb. 15, 1929; W. G. Keuffel to M.P.W. – K&E is going ahead with the making of several Vector slide rules to try out. Also, they have found the copy of Hedrick's tables.

May 3, 1929: K. Keller, K&E Vice President, to M.P.W. – K&E has finished the sample rules and have sent 3 to Professor Puchstein and 3 to him for a final test. In the letter they inform M.P.W. that they are enclosing an agreement for him to examine. This is to be signed at a later date when approved by all of the parties. The manufacturing cost is higher than expected with a catalog list price of \$16.00. They trust this will be satisfactory to him. Regarding instructions for the use of the new Vector rule; they already have complete instructions printed for their existing Log Log Slide rule, so they only want him to complete supplementary instructions to cover the Vector Slide Rule. (Author's insert: The \$16.00 list price was a big expenditure as it was about equal to the average worker's weekly salary at that time).

May 3, 1929: M.P.W. to A.F.P. – M.P.W. wrote telling A.F.P. that K&E has sent you three sample rules for examination, test, and any suggestions for improvement you care to make. M.P.W. also wrote, "I find that the rule is satisfactory. They however ignored my suggestion of having the scales of the trigonometric functions decimal." Also, mentioned was that K&E had sent a copy of the agreement. He presumed that a copy had been sent to both of them, and asked if Puchstein had any thing to say about the agreement.

May 20, 1929; A.F.P. to M.P.W. – A.F.P. says that after testing the rule he suggests a replacement of the LL0 scale by an A scale to give the rule more usefulness to students. As for the proposed agreement he said he would sign it, unless Weinbach would advise otherwise. A.F.P. wrote, "It is very important to see that K&E make suitable arrangements for marketing to students and others through their dealers and trade literature."

May 29, 1929: M.P.W. to K. Keller, K&E –M.P.W. says that he has checked out the sample rules and found them "fully satisfactory for all of the calculations encountered in electrical engineering problems." Instructions for its use and sample problems will be sent out within ten days. M.P.W. suggested some minor changes be made in the agreement. Inserting references to his Copyright, and adding the words, "party of the second part further agrees to properly advertise and push the sales of the same." He made a hand written note to himself on his copy of this letter that read, "These rules were not decimal, write again."

May 29, 1929: M.P.W. to A.F.P. – When writing to A.F.P., M.P.W. includes a copy of the 5/29 letter he sent to K&E. He says the main reason "for the insertion of the Copyright number at the bottom of page 1 instead of the Patent number is that Royalties should be paid not for the life of the Patent, which is only 12 years from now, but for the life of the Copyright, which is 28 years". He is finishing up the instructions and will send them for Puchstein to check and add to before he sends them to K&E.

June 1, 1929: K. Keller, K&E Vice President, to M.P.W. – K&E wrote saying they had received his 5/29 letter and shall change the agreement form accordingly. In the meantime, they said that they had loaned two rules to engineers at the largest telephone company (AT&T) to test and report back. K&E also enclosed for M.P.W. a May 25th response from the telephone company signed by Mr. Kruger, their Development Engineer. He said that the angle scales should be divided into degrees and decimals rather than degrees and minutes. K&E agreed with Mr. Kruger and said, “This point has come up before and we therefore, wish to submit it to you and Prof. Puchstein for your consideration.” Kruger also suggested in his report that radians be used instead of degrees on the rule. (Author’s insert: These letters from K&E over the past few months about sample rules are strange. They are repetitious and K&E is acting as if they had not heard Weinbach’s earlier discussions, or read his previous remarks, of the need for decimal scales and other features on the rule).

June 7, 1929: M.P.W. to K. Keller, K&E: M.P.W. responded that he fully agreed that the possibility of errors would be eliminated if the tangent and sine scales were in decimals instead of minutes. He said, “My students who have used two of the rules were quite disappointed to find these scales in minutes. A similar report came to me from the professor of another institution and to whom I loaned one of the rules you sent to me. I talked this matter over last summer with the younger Mr. Keuffel and another gentleman, whose name I do not recall, and attempted at that time to impress upon them the desirability of decimal scales like the one described in my paper “Vector Calculating Machines.” (Author’s insert: All of the scales in the picture of the Vector rule in his article as well as all of the many examples are in decimal degrees). In this 6/7 letter M.P.W. doubted that there would be a great demand for a slide rule with radian scales. He mentioned that he had previously suggested to them the desirability of placing a prominent line on the C and D scales at 57.3. This would permit rapid conversions from degrees to radians. He said he had completed a set of instructions and had sent a copy to Professor Puchstein to check and to make comments. Lastly he said, “I should like to hear from you of the possibility of changing the S, SI and T, and TI scales to decimals, so that I should make proper changes in the instruction notes”.

June 12, 1929; A.F.P. to M.P.W. – A.F.P. says he has gone through the instruction material M.P.W sent to him and is returning it with general suggestions, and comments on four items on pages 5, 7 and 10. He likes the way in which the instructions are written and may have more examples to send. However, he suggests Weinbach only wait a short time for these as we should turn the material over to K&E as promptly as possible.

June 14, 1929: K. Keller, K&E Vice President, to M.P.W. – K&E said, “Answering your letter of the 7th we have noted the following changes:

1. We all agree that the SI and TI scales should be divided to degrees and decimals instead of to degrees and minutes; 2. We will insert a line at $180/\pi$ equal to 57.3 on the C and D scales. Please advise the most suitable mark to designate this constant. We suggest the letter ‘R’. In the connection with the above two changes, please advise us whether the S and T scales on the lower body piece of the rule should also be divided to degrees and decimals or should they be made in the regular way divided to degrees and minutes?” K&E also wrote that in the meantime they had received another updated 6/7 report from

Mr. Kruger regarding the testing of the rule. A copy was enclosed for M.P.W. to examine and return comments to K&E.

The report from Mr. Kruger contained these recommendations:

1. Degrees and decimals should be used instead of degrees and minutes; 2. The S and T scales should be eliminated and replaced by a Cosh scale and a circular radian scale for use in converting radians and vice-versa; 3. The name of the rule should be “Complex Quantity” instead of “Vector”, since the rule enables one to handle a complex quantity directly. (Author’s insert: The last comment about handling a “complex quantity directly” points out the major feature of Weinbach’s design. This is the fact that “direct” solutions to complex hyperbolic functions such as $\sinh(u + j\theta) = A / \underline{\alpha}$ were easily obtained in a few steps by using his slide rule. This reference to solving problems “directly” means being able to obtain an answer by using only one sequence of continuous movements of the slide and the cursor. This is obviously preferred over an “indirect” process whereby one is forced to stop and write down the result of an intermediate step, or steps, and then use this result to restart the slide rule again in order to obtain the final solution).

Continuing on with their 6/14 letter to Weinbach, K&E said they have the following comments in connection with this and Mr. Kruger’s previous report:

1. We propose to move the minute and second marks (‘ and “) from the SI 1 scale to the C and D scales; 2. We do not agree with Kruger’s suggestion that we change our present arrangement of two SI and a TI scales to one SI and a TI scale; 3. We do not agree, as Kruger suggests, with adding a Cosh scale as we would have to omit the regular T scale to do this; and, 4. We would prefer to retain the name “Vector” to the somewhat vague name of “Complex Quantity” he suggests we use.

K&E further commented that we understand Professor C.E. Tucker of MIT is very much interested in this rule for some of his students. We are sending one of the sample rules to him, together with a copy of the new changes. Also, we are sending a copy of this 6/14 letter direct to Professor Puchstein.

June 20, 1929: M.P.W. to K. Keller, K&E – M.P.W. wrote, “Regarding your registered letter of June 14, I am indeed glad to learn that you have agreed; (1) to divide the circular trigonometric scales into degrees and decimals instead of degrees and minutes, and (2) to insert the line mark on the C and D scales to facilitate conversion from radians to degrees and vice versa. The marking with letter ‘R’ suggesting ‘radians’ is very good. With this mark, the extra scale in radians suggested by Mr. Kruger is not needed.”

Regarding other possible changes Weinbach said that;

1. Since the SI and TI scales would be in decimals it is imperative that the T and S scales should also be in decimals;

2. The changing of the minute and second markings from the SI1 scale to the C and D scales is very desirable;

3. He did not agree with Mr. Kruger’s suggested changes in the SI2 scale as the usefulness of the rule would be seriously impaired for most of the calculations;

4. The substitution of the TI scale as a SI scale for small angles, as suggested by Mr. Kruger, was not necessary, as the SI1 scale may be used for small angles;

5. He did not agree that the S and T scales be eliminated to make room for a Cosh scale. He said the S and T scales shorten numerous calculations, and the Cosh can be valued in a much shorter method than by the example given by Mr. Kruger;

6. He said, "I agree with you that the name 'Vector' is preferable to 'Complex Quantity' rule as suggested by Mr. Kruger. Neither of these names, however, suggest the more or less complete usefulness of the rule. It is not only a 'Vector' rule, but also a log-log rule, and as such is adapted to innumerable calculations other than vector calculations. My students, who have used the rule, are unanimously in favor of the name 'Log Log Vector' or 'Universal-Vector' as suggestive of the multiplicity of calculations to which the rule is adapted."

In this 6/20 letter, Weinbach goes on to say, "In summing up I would advise the rule be made with the agreed: (a) change the S, T, SI, and TI scales to decimals; (b) change of 'minute' and 'second' markings from the SI₁ scale to the C and D scales; and (c) mark 'R' at 57.3 on the C and D scales. With the rule constructed in this manner it will be suitable not only for such calculations as are met in communication network problems, but for any problem encountered in Electrical Engineering, or for in fact any problem including such as demand the conversions of complex numbers into polar expressions and vice versa, or hyperbolic functions of complex variables into either complex numbers or polar expressions."

June 24, 1929: A.F.P. to M.P.W. (With copy to K&E) – A.F.P. summarizes Kruger's two reports and generally agrees with the comments about them and the changes that were made by Weinbach and K&E. He is looking forward to receiving a copy of the instructions from Weinbach. Regarding the name, he said, "I prefer the name "Vector" to "Complex Quantity", in spite of the fact that Vector is a less accurate term from the point of view of Vector Analysis. However, since the complex quantity vector is used almost exclusively for electrical computations very little confusion should result. Hence it is appropriate to call it a Log Log Vector Slide Rule."

August 17, 1929: K. Keller, K&E Vice President, to M.P.W. (Copy to A.F.P.) – K&E wrote, "We have received the final comments and criticism from the various parties to whom we had submitted sample slide rules according to our previous correspondence and find nothing of importance has been reported besides the points of which we have written you already, consequently the final changes submitted by you with our letter of June 14th remain as follows:

1. Scales SI1, SI2, TI, S and T will be subdivided to decimals of degrees instead of to minutes;
2. The "Minute" and "Second" constant for small angles, which are on the SI scale on sample herewith, will not be placed on this scale but will be located on the C and D scales;
3. A constant, to be used for converting radians to degrees and vice versa will be located at 57.3 on the C and D scales and designated by mark "R";
4. This slide rule should be known as the "Log Log Vector" instead of just Vector. The name which we have selected, that is Log Log Vector, has been criticized but we agree with you that this name is about the best."

In this 8/17 letter K&E sent an original and two copies of the Agreement for M.P.W. to sign if satisfactory to him. They asked him when signed to please send these on to Professor Puchstein to sign, and then return to K&E for them to sign. They need this done before they can manufacture the slide rules, which they hope can be finished by the end of October. Also, they would like to receive the directions for the rule that he is working on as soon as possible. K&E ended the letter saying, "Trusting that this transaction will

turn out to your full satisfaction and be the beginning of many years of friendly relations between us.”

August 28, 1929: M.P.W. to K. Keller, K&E – M.P.W. fully agrees with the changes listed in their 8/17 letter. He further says that he mailed the signed Agreements to Professor Puchstein today. The instructions for the Log Log Vector are more or less complete with the exception that the various settings and illustrative examples are all in degrees and minutes. However, he would like them to send him a rule with the decimal scales so that he can recheck the various calculations and examples that demonstrate the usability of the rule. He ended the letter with the words, “Thanking you for the thought of friendly relations that are just beginning between us.”

August 28, 1929: M.P.W. to A.F.P. – M.P.W. mailed the signed Agreement, in triplicate, to him. He said, “I trust that the transaction as concluded will turn out to our mutual satisfaction.”

September 6, 1929: K. Keller, K&E Vice President, to M.P.W. – K&E sent him a copy of the fully signed Agreement. They will be sending a sample slide rule with decimal scales in about a week. They hoped this would allow him to finish the instructions by the time the rule is finished.

September 13, 1929: K. Keller, K&E Vice President, to M.P.W. – K&E said that the sample rule with decimal scales is being forwarded. This will enable him to recheck the instructions that he is completing.

September 18, 1929: K. Keller, K&E Vice President, to M.P.W. – K&E said that on the Log Log Vector slide rule we sent you we neglected to designate the following three gauge points on the C and D scales; minute (‘), second (”), and the letter “R” for the factor converting radians to degrees. These are being added to the lot of rules we are now making.

September 20, 1929: M.P.W. to K. Keller, K&E – M.P.W. has not yet received the rule they sent on 9/13. When received he will send the instructions within a few days. He takes pleasure in ordering 36 of the rules for his classes. Will they have leather cases?

September 24, 1929: A. H. Schmitz, K&E, to M.P.W. – K&E thanked him for the order of 36 rules. The \$16.00 price they quoted him was for Morocco (Black) cases. The price for Leather (Orange) cases is \$16.85. Let them know which ones he wished to order?

September 25, 1929: M.P.W. to K. Keller, K&E – M.P.W. said, “Conforming to or agreement, I am mailing you enclosed herewith a copy of instructions for the use of the Log Log Vector rule. A copy of these instructions was submitted to Professor Puchstein and he suggests that we add, for the sake of completeness, those formulated by him. I am enclosing the original copy that he has sent to me. I will leave the matter to your judgment but in case you include the additional information formulated by Professor Puchstein, then the instructions should go under joint authorship. Regarding the C scale on the rule the division lines at 206, 344 and 35 are longer than they should be. Change the number of rules in my last order from 36 to 37.” (Author’s insert: It appears somewhere in the five days between 9/21 – 9/25 Weinbach finally received a slide rule

with decimal scales, and in that short time was able to complete the revised instructions and send copies to K&E and Puchstein on 9/25. This seems to be quite an achievement).

September 25, 1929: M.P.W. to A.F.P. – M.P.W. sent a revised copy of the instruction notes to him along with this letter. He said that, these are identical to those he mailed to K&E, and, it took longer than expected as he was waiting for a rule with decimal scales. M.P.W. told A.F.P. that the additional information formulated by A.F.P. had been sent to K&E.

October 14, 1929: M.P.W. to A. H. Schmitz, K&E – M.P.W. wrote that the slide rules should be in Morocco cases, and ship 42 instead of the 37 previously ordered.

November 1, 1929: A. H. Schmitz, K&E, to M.P.W. – K&E informed him that the 42 Log Log Vector Slide Rules have been shipped today. The instruction books have not yet been received from the printer. They will be sent as soon as received. (Author’s insert: A copy of Weinbach’s original instruction notes are in the Archives. I compared line-by-line the text of this copy with the final instruction manual printed by K&E. Except for some introductory text added at the beginning by K&E, the rest of the entire manual was copied by them directly from his notes. However, none of the few additions to the instructions that had been suggested by Puchstein to use were included by K&E in the manual).

Later in November, when the instruction books had been printed, K&E released a newspaper story about the new “Log Log Vector Slide Rule”. The Archive files include a number of letters received by Professor Weinbach throughout the month of December from interested parties in other Universities and Companies. There is no way of knowing how many letters K&E received, but the response was very good, and over the month orders started coming in.

The Log Log Vector Slide Rule, K&E Model No. 4093-3, was now a reality. Historically it was the first slide rule with hyperbolic scales to be manufactured and sold to the public. It is obvious from the Archive’s records that Professor Weinbach had almost single handily promoted and developed the slide rule and its manual of instructions. Also we have found that K&E and Puchstein had only limited roles in creating its design and completing the instructions.

Pictures of the front and back scales of the new rule are shown in Appendix 2 following this Article.

It is interesting to note that after all of this time, and with so many repetitious letters and suggestions back and forth, the final version of the rule was the same as the “blueprint” design of December 14, 1928. The Front Side had the “general scales” that both Weinbach and Puchstein wanted to have to make the rule more useful to users, namely:

|| L, LL0, DF || CF, B, CI, C || D, LL3, LL2 ||

The scales on the “hyperbolic” back side had been simply rearranged from Weinbach’s original design, except for the CI scale that was moved to the front, and the S and T scales were added. The Back Side had these scales:

|| Sh₁, Sh₂, Th || SI₁, SI₂, TI || D, S, T ||

Most important was the fact that all of the trigonometric and hyperbolic scales were finally in decimal degree format as Weinbach had wanted them to be from the beginning.

His notes show that the rule was placed on sale in October, and in the last months of 1929 a total of 115 Log Log Vector Slide Rules were sold for \$1,840. A physical inspection of the slide rule shows there are 19 scales in all, with the S11, S12, and T1 scales acting as complementary numbered dual scales. When measuring the rule one finds the scales are not 10 inches long, as advertised by K&E. The S11 scale is the longest at 9 15/16 inches (≈ 25.24 cm). The rest of the 18 scales are shorter, and all of the same size at 9 13/16 inches (≈ 25.00 cm). The overall length of the rule is 12 1/2 inches (or ≈ 31.75 cm), and width is 1 9/16 inches (≈ 4.00 cm). The slide rule body is mahogany wood covered by white plastic, and is held together by metal brackets. A screw in each bracket allows for adjustments in order to keep all of the slide rule scales in alignment.

The layout of the scales did not change throughout the years in which the rules were manufactured. The logos underwent minor changes with the Patent dates on the 1929 version replaced in 1936 by the Patent Numbers. (Author's insert: I have another variation in my collection that is completely blank with no logos). The original cursor was not framed; it was replaced in 1936 by an improved metal framed one.

Slide Rules could be ordered in two different colored cases, with the letter "S" after the number denoting the more expensive case. The K&E 4093-3 came in a pebbled Morocco (black colored) box like case for \$16.00. The K&E 4093-3S came in a fancier chamois lined orange-brown sewn leather case for \$16.85.

The instruction manual for the K&E 4093-3 was copyrighted and issued in 1930. A picture of its cover is shown in Appendix 3.

Following the successful introduction of the Log Log Vector Slide Rule in late 1929 there was no important correspondence between the parties for about six months. Then in June, Weinbach received a letter from K&E.

June 10, 1930: K. Keller, K&E Vice President, to M.P.W. – K&E said that they have had occasional calls for a Log Log Vector Slide Rule with a 20 inch scale length, and were thinking about making a small quantity of them. They will be exactly the same arrangement of scales as the 10 inch. The list price of the 20 inch will be \$32.00, and we will pay a 5% royalty in accordance with our arrangement. Please advise us if we may proceed with the manufacture of these, and if the list price meets with your approval.

June 23, 1930: M.P.W. to K. Keller, K&E –M.P.W. said that the manufacture of the 20 inch rule and list price meets with his approval. He asked K&E if it would be possible to add a Cosh scale in place of the S scale on the new 20 inch rule.

August 6, 1930: K. Keller, K&E Vice President, to M.P.W. – K&E wrote him saying that you will recall we discussed the Cosh scale last year, and although we all agreed it would be desirable to have a Cosh scale we (K&E) did not think it advisable to omit either the T or S scale. We have again considered this and cannot figure out any arrangement that would allow for the addition of this scale.

October 8, 1930: M.P.W. to K. Keller, K&E – M.P.W. said that the sale of the ten inch rule had gone pretty well here at our University with over one hundred being sold so far this year. He said that he has had several inquiries regarding the 20 inch rule they informed him of in their 6/10 letter. He would like to have one of the 20 inch rules for demonstration purposes and wonder if they could present him with a complimentary one. Thanking you in advance.

October 14, 1930: K. Keller, K&E Vice President, to M.P.W. – K&E responded that the 20 inch rule will be ready by the end of November and we will send you one.

January 11, 1931: M.P.W. to K. Keller, K&E – M.P.W. was wondering if the 20 inch rule is ready, as he has had some inquiries regarding it.

January 30, 1931: M.P.W. to K. Keller, K&E – M.P.W. wrote, “Permit me to thank you for the complimentary twenty-inch Log Log Vector Slide Rule which I received a few days ago. Like any other Keuffel and Esser product it is fine and well made.” (Author’s insert: Prominently displayed on the wall of the “Faculty Lounge” in the Electrical Engineering Building of the University of Missouri-Columbia are two slide rules in a glassed-in frame. A picture of these is shown in Appendix 4).

This concludes the Phase 1 portion of this Article. It ended in January 1931, and there was very little correspondence in the Archives before June 1933, the start of Phase 2. One interim item worth mentioning is a letter dated February 9, 1932, from K&E to M.P.W., regarding the Frederick Post Model 1459 (Hemmi Model 152) Electrical Engineer’s Universal Duplex Slide Rule. This, K&E said, was being sold against our Vector rule, and asked him to study a sample they sent to him. On February 26th he sent K&E a five page letter showing details of the operations of the Hemmi rule. Weinbach’s conclusion was that, “The Japanese rule #1459 is therefore limited in scope and incomplete for the various calculations the electrical engineer meets in his daily work. The name ‘Universal’ attached to this is misleading”, he said. In the same letter he also reviewed the Hemmi No. 154, 20 inch rule. His comments were that, “... their #154-20” duplex rule like their #1459-10” is limited in scope and incomplete compared with our Log Log Vector.” (Author’s insert: Weinbach was correct in his assessment of the Hemmi slide rules as his design was much better. Also, K&E’s concern was premature as the expected competition never materialized. This was due to the result of two historical developments in the 1930’s; (1). the Great Depression that devastated all business, and (2). the deteriorating relations with Japan that severely limited imports into the U. S. A.).

He ended his 2/26 letter by making the following pitch to K&E about making more of an effort to advertise the Vector rule: “Since these rules, as you say are being sold in competition with our Log Log Vector, I wonder whether some scheme of bringing to the attention of teachers and engineers in general the advantages of our rule as a saver of time and mental effort would not be advisable. I have been informed that our rule is not used at Washington University, St. Louis, nor at the University of Kansas. One of my former students, now an instructor at Yale, informs me that the rule is not known there; similar information comes to me from another who is now an instructor at Pennsylvania State College, and still another who is taking post-graduate work at Purdue University tells me that the rule is unknown at that institution. In view of this, I believe that it would be desirable and I feel quite certain it would pay to inform prospective users of the advantages of the Log Log Vector rule. Personally I shall be glad to cooperate with you in this matter and will write the technical literature on the subject, if you so desire.”

K&E’s response to him on March 4th was, “We wish to thank you for your detailed letter of February 26th, which plainly shows the advantages of your rule over the Japanese imitation.” Their letter went on to say that they had circulated information to all of the universities, “but we find it hard to get the names of the men at the universities and colleges who are directly interested in this subject. Could you give us a list of these men

so that we could write to them? Also, in case a professor should desire additional information not contained in the instruction book, could we refer him to you for such information?”

Weinbach followed by sending K&E a list of many professors’ addresses, and in late April and early May 1932 letters went out to them advertising the virtues of the Log Log Vector slide rule. (Author’s insert: It is obvious from this exchange of correspondence that K&E, the leading slide rule manufacturer in the Country, had not done much in the way of marketing in the intervening two years since the introduction of the rule. This was a shame, as Weinbach’s rule was far superior to anything the competitors had. For eighteen years, 1930-1948, his were clearly the preferred slide rules to use for directly solving problems involving complex hyperbolic functions. It seems K&E never did really recognize or understand the importance of his unique design).

Phase 2, 1933-1935: Regarding Weinbach’s concerns about royalties

This phase begins with a June 14, 1933 letter from Weinbach to Carl M. Bernagau, V. P. and Treasurer of K&E., containing the following:

“I have received recently a number of letters from teachers of Electrical Engineering regarding your Decitrig slide rule. They desire to know its distinguishing features as compared with the Log Log Vector to the solution of Vector problems such as are met in Alternating Currents.

That I shall be in a better position to answer such queries I procured a Decitrig rule and I find that the folded, decimally subdivided trigonometric scales are precisely identical with those on the Log Log Vector devised by myself.

The main calculations for which the decimally subdivided folded trigonometric scales of the Log Log Vector rule were designed pertain to the conversion of exponential functions into complex numbers and vice-versa. Your Decitrig rule embodying, as it does, the same scales would directly displace the Log Log Vector for the major purpose for which it was devised and designed. I take it for granted - however that the embodying of these trigonometric scales in the Decitrig rule without my approval thereto was done unintentionally.

I realize that it may be a wise move to produce a rule to compete with the imported Japanese rule, which I examined and made a complete report on at your request. I trust however, that you will also realize the justification of my writing to you regarding this matter, for I have the utmost confidence in the integrity of the Keuffel & Esser Company to carry out whatever agreement they enter into.”

(Authors insert: The underlined emphasis in the letter was added by Weinbach. The Decitrig slide rule he was referring to was the K&E 4091, Log Log Decitrig Slide Rule, newly introduced in the 1933 K&E Catalog. Other than Weinbach’s Log Log Vector rule, introduced three years earlier, K&E had never marketed a slide rule with decimally divided trigonometric scales. Also introduced at the same time was the K&E 4090, Log Log Trig Slide Rule that was identical except that it had trigonometric scales divided into degrees and minutes. Part of the description by K&E of these slide rules in the 1933 Catalog included the following wording: “Nos. 4090 and 4091 are alike except in the subdivision of the trigonometrical scales; which when decimally subdivided, like the No. 4091, find their principal use in electrical engineering calculations.” Also included by

K&E was, “This easy and rapid solution of the right triangle is particularly valuable in Vector problems, which involve frequent changes from polar to rectangular co-ordinates and vice-versa.” We can conclude that the design of the K&E 4091’s decimally sub-divided trigonometric scales, together with the 1933 Catalog descriptions, were the reasons behind Weinbach’s letter of June 14th).

On June 23rd Carl M. Bernagau, V. P. and Treasurer of K&E. responded as follows: “We acknowledge receipt of your letter of June 14th. We note your remarks regarding your viewpoint on relations between the Log Log Vector and the Log Log Decitrig rules, and will give this matter our careful attention as soon as the report, which we have asked our Engineering Department for, has been received.”

On September 11, 1933, over two and one-half months later, Weinbach received a response from K. Keller, Vice President of K&E. In this letter K&E gave reasons why they felt their new Log Log Decitrig Slide Rule did not in any way conflict with the agreement made with him regarding the Log Log Vector rule. They said this new slide rule was never intended to cover the field of the Vector rule, but was merely an improvement over their existing Log Log Duplex Slide Rule. They referred him to his March 13, 1928 letter with the enclosed article on “Vector Calculating Devices”, in which he described a slide rule with the following outstanding features:

- (a). The rapid conversion of vector quantities from the exponential form into equivalent complex numbers and vice-versa, and
- (b). The evaluation of hyperbolic or trigonometric functions of complex variables into equivalent plane vectors, either expressed exponentially or in terms of complex numbers.

In regard to (a) above they reminded him that in their letter of March 22, 1928 they said the idea of a slide rule for vector calculations was not new to them as they had done previous work along those lines. K&E said that as far back as 1921 their Mr. Campbell had discovered the arrangement of scales by means of which the conversion of vector quantities from the exponential form into the equivalent complex numbers, and vice-versa, could be readily performed. In February 1922 they made six slide rules of this design in 20 inch length called the “Electrical Research Slide Rule”. These were submitted to parties they thought might be interested, the best known being Bell Telephone Laboratories (BTL). Then in 1924 due to the interest created they made special rules for the BTL using the same arrangement of the scales for solving the right triangle. As for decimally sub-divided trigonometric scales being devised by him, K&E dismissed his claim by saying that for many years, prior to 1928, they had made special slide rules with such decimal divisions. Specifically in 1922, decimally sub-divided trigonometric scales were on some special slide rules made for the U.S. Department of Agriculture.

They did acknowledge that his ideas covered by paragraph (b) above, and Puchstein’s Patent, were the original sources to call their attention to the use of the slide rule for problems involving hyperbolic functions.

The letter included the following comments by K&E: “In the summer of 1928 you called us at our factory and after several conferences with our Mr. A.W. Keuffel and Mr. Campbell, a tentative arrangement of our Vector Slide Rule was agreed upon. The arrangement of scales which was finally adopted, as shown in our blueprint of August 16, 1928, has the Log Log scales and the folded scales of our Log Log Duplex Slide Rule,

and the arrangement of the trigonometric scales double-numbered and inverted with respect to the D scale, which is the same relative arrangement for solving the right triangle in one operation as that described above in our Electrical Research Slide Rule of 1922. The hyperbolic scales and the additional sine and tangent scales on the body of the rule were added at your suggestion.” This 1921 arrangement, they said, was identical with that now used by the Log Log Vector and Log Log Decitrig slide rules; that is, the trigonometric scales and inverted logarithmic scale, which is used in conjunction with them.

Mr. K. Keller, Vice President of K&E ended the September 11th letter with: “We sincerely trust that the above history of the case is sufficiently clear for you to understand our position in the matter, and that with all of the facts now at your command you will agree with us that the Log Log Decitrig Slide Rule does not in any way conflict with the agreement made with you regarding the Log Log Vector rule.”

Needless to say, Professor Weinbach did not agree with a number of points in K&E’s letter, and on November 22, 1933 wrote to K. Keller, Vice President. He said that he had made a careful analytical study of K&E’s 9/11 letter and was forced regrettably to take exception to their statement that the arrangement of the trigonometric scales on their new trig and decitrig rules were identical with those on the “Electrical Research” rule devised by their Mr. Campbell. Weinbach’s letter went on to say, “A casual comparison between the scales will indicate beyond doubt that they are not identical. In accordance with your own description, the trigonometric scales on the ‘Electrical Research’ rule were designed to be used in conjunction with an inverted AI scale. A similar comparison will indicate, on the other hand, that the trigonometric scales on the new Trig and Decitrig rules are absolutely identical with those described in our paper VECTOR CALCULATING DEVICES covered in our copyright, and embodied on the Log Log Vector rule.” Also, the Decitrig rule and the Log Log Vector rule are decimally divided while those on the “Electrical Research” rule are in degrees and minutes.

Weinbach continues, “It seems clear and convincing from the above analysis that the trigonometric scales on the Trig and Decitrig rules are identical in every respect as to lay-out and application to those on the Log Log Vector rule covered by our contract, and that they are essentially different in lay-out from those used on your ‘Electrical Research’ rule. We wish to say in all frankness that had you placed on the market a rule with trigonometric scales identical to those on your Electrical Research rule, we would not have raised any questions, for such a rule, being essentially different from the Log Log Vector, would not have been in violation of the terms of the contract.”

He next discusses the Hemmi–Post No. 1459 rule. K&E had previously sent this to him to examine as they said it was being marketed in competition with his Log Log Vector rule. His report to them showed that this Hemmi–Post rule did not have many of the features of his rule. K&E had thanked him for his report and acknowledged the obvious superiority of his rule. However, Weinbach surmised, in spite of this information they had unilaterally decided to develop and market the Trig and Decitrig rules without informing him.

He went on to say, “In connection with this matter, permit us to also refer to our contract which in its preamble states: ‘Whereas the parties of the first part have designed and invented a slide rule with trigonometric, hyperbolic and logarithmic scales so disposed that conversions of vector quantities from exponential to the complex form and

vice versa may be obtained with ordinary slide rule ease and rapidity as described in the attached paper and as covered by United States Copyright.....” (Authors insert: The underlined emphasis above was added by Weinbach. Where he refers to “we” and “us” in different places in the letter he means “Puchstein and Weinbach” together).

He continued by saying, “Note please that the trigonometric scales which are specifically and explicitly referred to in the preamble of our contract, are precisely the very ones embodied in the Log Log Vector rule manufactured and marketed by yourself under the terms of the contract, and which you are now using on the Trig and Decitrig to all appearances in violation of the contract. We felt, as we stated, in our letter to Mr. Bernagau dated June 14, 1933, that the use of these scales on the Trig and Decitrig rules with no reference to our contractual terms was done unintentionally. This feeling is still with us, for our view of what is stated in this letter, it is inconceivable that you should not agree with us that the Trig and Decitrig rules come within the scope of our contract, and subject, therefore, to the same terms. In the expectation that this matter will be taken of in a just and equitable manner, we wish to assure you of the continuance of our cordial relations and cooperative effort.”

On February 3, 1934 Weinbach sent a short follow-up letter to Carl M. Bernagau, V. P. and Treasurer of K&E. In it he said the following: “Regarding the Trig and Decitrig rules covered in my letter dated November 22, 1933, we wish to say that we trust that such an eminent Firm as Keuffel & Esser will do what is equitably right.”

(Author’s insert: It might be helpful at this time to show a listing of the scales of the slide rules referred to above. These are as follows:

- 1922 - Electrical Research rule: || LL1, LL2, A || B, S, T || AI ||
- 1928 - Vector slide rule in the paper: || S, S, T || Th, Sh, Sh, C || D, CI ||
- 1930 - Log Log Vector rule: || Sh1, Sh2, Th || SI1, SI2, TI || D, S, T ||
- 1933 - Log Log Trig & Decitrig rules: || LL0, A || B, K, CI || T, S2, S1 ||

It is the trigonometric scales on the “Electrical Research” rule that are being challenged by Professor Weinbach. His position is that the way the scales on the Electrical Research rule are used they do not compare with those on any of the other rules. He says that any comparison K&E makes using the “Electrical Research” rule should be ignored as it is obvious when looking at the scale layouts there is no comparison. The issue, he maintains, should come down to comparing how the scales are used on the last three rules. His contention is that the trigonometric scales on the 1933 Log Log Trig and Log Log Decitrig rules are basically the same as those on the Vector slide rule in his 1928 paper “Vector Calculating Devices”, and in his 1930 Log Log Vector rule. It is beyond the scope of this Article to explore the history and technical details involving these different slide rules. Needless to say the positions of Weinbach and K&E in this matter were far apart. However, the Author feels Weinbach seems to have the stronger argument regarding the similarities that he shows exist between the scales).

Over four months passed before Weinbach received a response from K&E regarding his letter of November 22, 1933. This came in the form of a five page letter dated March 30, 1934 from C. M. Bernagau, V. P. and Treasurer of K&E. This reviewed all of the previous points previously covered without K&E changing any of its already stated positions. They again pointed out that they had in the early 1920’s developed a number of

rules with scales similar to the Trig and Decitrig. Details of these were included in the letter. Also, they said that decimally divided scales were not new to them, for as far back as 1923 they had offered such scales to at least one client. They said that he has misinterpreted the contract as the preamble paragraph that mentions the trigonometric, hyperbolic and logarithmic scales is only meant to show that all three types of scales are required for the Log Log Vector rule to complete its operations. They further said, the licensing Agreement that includes Puchstein's Patent and Weinbach's Copyright, and his descriptive article "Vector Calculating Devices" all show and include hyperbolic functions which are the essential feature of any Vector rule to which the agreement applies.

In finalizing the letter K&E said: "We have gone over this matter again and again, but can only come to the same conclusion that we did in our last communication on the subject, namely – that the Log Log Trig & Decitrig rules do not, and never were intended to cover the field of the Log Log Vector rule but that they are a natural development from our Log Log Duplex rule. In this improved form, we have not made any basic changes except that we have amplified the trigonometric scales by our application of our discovery of December 1921, and specifically by making them precisely like our 10" Vector rule of 1925. From the above statement, showing the development of our Trig & Decitrig Slide Rules, we feel certain that they come neither legally or morally within the scope of our contract with you and Prof. Puchstein, which covers the Log Log Vector rule, and we hope that after considering the situation in light of our present letter, you will concede that our position is correct."

Three weeks later, on April 23, 1934, Weinbach responded to C. M. Bernagau, V. P. and Treasurer of K&E, by saying: "We are painfully disappointed by the course you have taken regarding the Trig and Decitrig rules as outlined in your letter of March 30, 1933 in answer to mine of November 22, 1933. Your interpretation of our contract is extremely unfair to say the least. We do not subscribe to this interpretation." (Author's insert: Where underlines are shown they are by Weinbach).

He continues, "Through the publication in the Journal of the American Institute of Electrical Engineers of our copyrighted scales embodied in the Log Log Vector, Trig and Decitrig rules, and otherwise through direct contact or correspondence, every attempt has been made by ourselves to acquaint teachers, students and engineers with the application of these scales to the solution of engineering problems. Now that we have succeeded in creating a credible demand, you attempt by misinterpreting our agreement to avoid the payment of royalties on the major application of our invention."

Weinbach ends by saying, "We are very sorry that you have created a most unpleasant situation. This letter is written to you in the expectation that you may be inclined to take a saner view of the matter."

K&E's answer to Weinbach's April 23, 1934 letter was from C. M. Bernagau and was dated May 21, 1934. K&E said, "We received your letter of April 23rd, from which we regret to see that you do not agree with our viewpoint of the situation expressed in our letter of March 30th."

"We realize of course that you are naturally influenced by your personal feelings, and therefore we fear that a continuance of our present correspondence would be of no particular purpose; on the other hand, we would be very sorry to leave you under the impression that we had done you an injustice. We would ask you therefore whether there

is a chance of your coming East during the approaching vacation season, as a verbal discussion of the matter might clear the situation.”

The result of this letter was a meeting on July 12, 1934 between the parties in Atlantic City. Weinbach’s notes of this say, “I let myself be cheated. Because of poor health at this time, my friends advised me to drop the matter and make the best of a bad deal. I advised the Company, however, that I would be in Atlantic City in July. Mr. Bernagau and Mr. A.W. Keuffel came and we discussed the whole affair. I proposed to them at this meeting that since they are using in the Decitrig rule my three decimally divided trigonometric scales, which they were licensed to use in the Log Log Vector, they should pay me a royalty one half as much as they pay on the Log Log Vector which has in addition three hyperbolic scales. Needless to say they did not agree to my proposal.”

As a follow up to the meeting a letter was sent on July 19, 1934 from C. M. Bernagau, V. P. and Treasurer of K&E to Weinbach. K&E regretted that they were unable to agree to his proposal because of legal as well as practical reasons that were explained to him at the meeting. They also said that they had resubmitted this matter to their patent attorney who says the Agreement between the parties only covers the Log Log Vector slide rule. They said, “Our patent attorney assures us that the Log Log Trig and Log Log Decitrig rules do not infringe the Puchstein Patent, nor are their features shown in your article ‘Vector Calculating Devices’ or in the Copyright.”

The letter went on to say, “There may a possibility that the introduction of the Trig and Decitrig rules will somewhat adversely affect the sale of the Log Log Vector Slide Rule. For this, however, we cannot hold ourselves responsible. No doubt somebody else would eventually have brought out similar rules.....”

“We are willing however, as proof of goodwill towards you and in recognition of what you may have done for the introduction of the Log Log Vector rule but solely as a voluntary act on our part and without admitting any legal obligation in any shape or manner, to guarantee that the royalty payable under our Agreement of September 5, 1929 will not be less than Five Hundred Dollars (\$500.00) in any one year, during the life of the Agreement. We could undertake this, however, only while such voluntary action on our part is accepted by you in the spirit in which it is tendered, as a token of goodwill to be reciprocated by you in the same spirit.”

(Author’s insert: Weinbach’s reaction to this letter was one of dismay as revealed by notes he made about the letter. In these he said, “Their argument now is that I am actually not entitled to anything. Their patent attorney has advised them that because of our joint Agreement with the Company then we (Weinbach and Puchstein) are one and the same under the law. Therefore Puchstein’s Patent invalidates my Copyright. This statement is definitely an expression of intention of an attempt to invalidate my Copyright unless I submit to their counter proposal of a minimum Royalty of \$500 on the Log Log Vector rule, for the life of the Agreement.”).

Around noon, on the same day as the above 7/19 letter, a Telegram from A. W. Keuffel was sent to Weinbach asking if he could meet with him that evening. As a result of that meeting and further exchanges, K&E, without changing its position regarding the controversy that had arisen, agreed to increase the Royalty payments. They would guarantee to pay a minimum Royalty of \$625 (\$500 to Weinbach and \$125 to Puchstein). This would be paid annually from January 1, 1934 to December 31, 1947. As previous

arrangements with regard to Puchstein had gone through Weinbach they asked that he contact him to obtain his approval to this change in their Agreement. (Author's insert: This Agreement was negotiated at the depth of the Great Depression. At that time \$500 could purchase a new automobile. Also, the Royalties for the previous four years had only averaged about \$280. So, while K&E felt it was being generous, that was not Weinbach's sentiments. He felt he was entitled to much more and was most unhappy).

Just as it seemed things were about to be resolved a new problem arose. About a month had gone by before Weinbach returned to Columbia, and on September 4, 1934 he sent C. M. Bernagau a letter regarding the duration of the Royalty payments. K&E had said they would end on December 31, 1947. He said in this letter that on his return he had checked the correspondence with a view of informing Mr. Puchstein of the proposal they had tentatively agreed on. Then he said, "Before writing him however, it is imperative that a conflicting statement be cleared up so that further difficulties regarding the matter will be avoided in the future. During the conversation you mentioned the fact that since the life of the Agreement extends for the duration of the Copyright the minimum Royalty on the Log Log Vector rule will be in force for the balance of the Agreement, that is for a period of fourteen years. You were apparently under the impression that the duration of a copyright is 20 years. Actually the duration of a copyright in accordance with Sect. 23 of the Copyright Law, as stated in Copyright Office Bulletin No. 14, July 1922, is twenty eight (28) years. Please have this matter checked up so that any possible ambiguity in the matter be completely cleared."

K&E's answer came in a letter to him from A.W. Keuffel on October 2, 1934. It was not what Weinbach wanted to hear. They had reviewed the past correspondence and his last letter and said, "You are quite right in your statement that the life of a copyright is 28 years and not 20 years. This, however, has nothing to do with the case, as in our letter of July 19th we clearly showed that entirely aside from the question of whether or not a slide rule is subject matter for copyright, the Puchstein Patent invalidates the Weinbach Copyright. Consequently, in his conference with you in Atlantic City on July 19, 1934 our Mr. A.W. Keuffel stressed the fact that you could afford us a monopoly only during the life of the Puchstein Patent, the expiration date of which is May 25, 1941. However, as this would only cover the next seven years and as we wanted to be extremely liberal in our offer, we voluntarily extended it, at Mr. A.W. Keuffel's conference with you, for another seven years, which was an arbitrary period and bore no relation to the termination of your copyright." The letter went on to remind Weinbach that he had agreed to this in their conferences with him. It continued by saying, "It is clear, therefore, that the Agreement of September 5, 1929 shall terminate December 31, 1947. Kindly, therefore, take this matter up with Prof. Puchstein and let us have an acceptance from yourself and him without delay. We are sending three copies of this letter, the original of which you will both sign at the bottom, in the spaces indicated, to signify your acceptance, and return to us."

There was an immediate and lengthy answer on October 8, 1934 from Weinbach to A. W. Keuffel. He restated his previous positions and said that in its present form the letter of October 2nd could not be signed. He said the letter was confusing and suggested that instead of using the letter there should be a separate form for the parties to sign as a Supplement to the Agreement of September 5, 1929. He reminded them that it would take

some time to acquaint Puchstein with all of the details of what had transpired, and obtain his consent. So, the Supplemental Agreement should be as concise as possible and not subject to misinterpretations. Weinbach then drafted the terms of what he felt the wording of the Supplemental Agreement should be. (Author's insert: This was a major turning point in the negotiations as by this time Weinbach was obviously worn down, and as a result he bowed to K&E's demands. He showed this by including this wording they wanted in his draft: ".....that the annual royalties payable to them jointly under the Agreement of September 5, 1929 will not be less than \$625.00 for any one year for the fourteen year period beginning with January 1, 1934 and ending with December 31, 1947.").

Two days later on October 10, 1934 Weinbach mailed a long letter to Puchstein. In this he explained what had developed with K&E in the past year and a half, and sent copies of the letters exchanged between him and K&E. He said, "Your reading of this correspondence will acquaint you with my contention in this matter and their attitude regarding it." Later in the letter Weinbach goes on to say, "The question is what can we do? We may go to a court of law for a decision as to whether we do have a contractual interest in their Trig and Decitrig rules. Is this advisable considering the costs of litigation, the time it will take, and the possible doubtful outcome? Shall we accept their offer, which they claim to be '*generous and liberal*'? My own personal reaction in the matter is that we accept their offer of a minimum royalty of \$625.00 per year to be paid for a period of 14 years and close with them at the end of that period. Please study this problem carefully. I assure you that I have done all I could to protect our joint interest from the point of view of time and expense. Trusting to hear from you at your earliest convenience....." (Author's insert: This letter to Puchstein was sent to his home address as he had left Ohio State University. He was now employed as Chief Engineer at Robbins & Myers, Inc., Manufacturers of Electric Motors, Generators, and Fans, in Springfield, Ohio).

On October 16, 1934 Puchstein answered. He said, "If the guaranteed minimum Royalty of \$625.00 for a period of 14 years from January 1, 1934 to December 31, 1947 to us jointly is the best we can get it seems best to accept it rather than engage in litigation, and I will agree to this. However, it seems clear from your letter and also from my early correspondence with them that they have in a manner violated their agreement with us. I invite you to the copies of my correspondence with them and with Prof. A. E. Kennelly of Harvard University, which are enclosed. These I wish returned when you are through with them. You may take such action as will best conserve our interests against those of a firm which has not followed the highest scruples. In their letter of Dec. 8, 1921, they stated that they had done no work along the lines I had indicated. See next to last paragraph of Jan. 26, 1922 to Prof. Kennelly. A short time later, I received from K&E a letter stating that they had done such work, but they gave no details. I then mistrusted them. My letter of Dec. 21, 1921 – fourth paragraph, in making for me what they called the (20") "Electrical Research Slide Rule of 1922" they replaced my scale arrangement by an inverted A scale. How much credit they should have for this I do not know but it seems clear the whole thing was the result of my initiative. Also the rule they furnished had one serious defect – my letter of March 16, 1922, in that some necessary gauge marks were omitted on the A scale and on the C scale. In any event their ideas did

not have enough steam to sustain them until after you made the present arrangement with them and they missed the good market of 1922-29.”

(Author’s insert: Unfortunately copies of the letters Puchstein refers to are not in the Archive files. They were evidently returned to him by Weinbach as requested. So, we can only rely on Puchstein’s statements implying that what K&E claims were some of their early discoveries were actually taken from him. It is obvious from the information Puchstein furnished on 10/16, about his past dealings with them, that he had little regard for K&E. One can only wonder what Weinbach could have done with this information if he had first contacted Puchstein sixteen months earlier, in June 1933, before he wrote to K&E about the Trig and Decitrig problem. However, at this late date, October 1934, Weinbach probably felt he was too far along to raise new issues with K&E. Also, “times” were bad for everyone. In light of this he may have considered that the Royalty payments offered by K&E should be accepted. The “good market of 1922-29” that Puchstein mentions, is in reference to the “roaring twenties”. These were followed by the “great depression” that came after the stock market crash of 1929. All business and University enrollment was down significantly throughout the 1930’s. Perhaps K&E thought the introduction of the new Trig and Decitrig rules would help boost their declining sales. However, as we have read here, K&E handled this entire matter very poorly).

On November 20, 1934 Weinbach sent a follow up letter to A. W. Keuffel that said, “.....regarding the Supplement to our Agreement. It is now more than six weeks since it was mailed to you”.

Another month was to pass, and on December 19, 1934 the Attorney for K&E, Frederick Griswold, Jr., wrote Weinbach. He enclosed three copies for signature of an Agreement Supplementing the existing one of September 5, 1929. This provided for the payment of annual Royalties in the language they had previously agreed upon, i.e. \$625 from January 1, 1934 to December 31, 1947. They were either to execute or reject the agreement. Of course if they rejected the Agreement he said, “..... our present offer would, of course, be null and void.” Carl A. Berganau, V. P. and Treasurer of K&E, had already signed the Supplemental Agreement on December 18, 1934. On December 26th Weinbach signed it and mailed it on to Puchstein who signed it on December 29th, and then forwarded the original on to K&E. (Author’s insert: In Weinbach’s notes about this signing he said, “The whole deal was disgusting in the extreme....a supplementary agreement was signed December 18, 1934....this permitted myself to be cheated out of some ten years of the life of the Copyright. From this time on I had nothing much to do with the Company.”).

This concludes Phase 2 of this Article. In retrospect this was a most unfortunate episode in Weinbach’s and Puchstein’s relations with K&E. In reading through the Archives records it seemed that K&E never did understand or appreciate Weinbach’s arguments. On Weinbach’s part he was baffled by the legal and historical defense that K&E mounted against his concerns. K&E kept falling back on events in the early 1920’s, before Weinbach entered the picture and that he had never heard about before. So, no matter what Weinbach thought were his Copyrighted designs K&E claimed that they had already discovered them. The knowledge of past events that Puchstein had might have tipped the balance in their favor, but he was brought in way too late for these to be a factor. By wearing Weinbach down K&E prevailed. However, it does seem in reading the

Archives that Weinbach presented a much stronger position. One can only surmise what might have been the outcome if Weinbach and Puchstein were to have had the means then to hire an Attorney to represent their interests.

After December 1934, except for the annual Royalty payments, there is a big void in any communication with K&E. The Archive files for the years 1935, 1936 and 1937 are empty of any other correspondence. In fact, the only letter in those three years is one dated March 2, 1937 from Puchstein to Weinbach. This was to express his pleasure that K&E had paid the 1936 Royalty to him, and because of increased sales it was for an amount higher than his \$125 minimum written in the Agreement.

Then in early 1938, on February 28th, Puchstein mailed Weinbach a copy of a clipping from the "Industrial Equipment News". It was a K&E advertisement for "an improved slide rule with a new arrangement of the trigonometry scales". This was for the newly introduced K&E 4080, LL Trig Duplex, and the K&E 4081, LL Decitrig Duplex, Slide Rules. The Instruction Manuals for these rules had a 1937 Copyright date. These rules replaced the K&E 4090, Log Log Trig, and the K&E 4091, Log Log Decitrig slide rules of 1933 that were the cause of Weinbach's and Puchstein's previous fight about Royalties. In his letter Puchstein said, "This rule undoubtedly uses in part the same scales, or a modification thereof, as the Vector slide rule. I assume that this product comes under our Agreement with them, but there is a possibility that they may not so interpret it. We had in mind more the vector applications, whereas they now seem to have added the features of multiplication and division to enter a different field. I am wondering if you should write to them and have the matter settled, or if it would be better to wait and not incense them."

Puchstein follows-up with another letter to Weinbach on May 4, 1938. In this he says, "Last February I wrote you in regard to a new type of slide rule which employs some features of the Vector slide rule and is directed more to non-electrical engineers. This was put on the market by Keuffel and Esser Company. It is possible that this may be an infringement and that they do not regard it as coming within the area covered by our Patent. Their plans probably should be looked into. Possibly you have overlooked my letter."

Weinbach responded to him on May 9th, by saying, "I confess that I do not know how to handle the situation regarding this new LL Trig Duplex rule which K&E brought out a few months ago. You will recall that a similar situation arose a few years ago when they put on the market their Trig and Decitrig rules. I had a long correspondence with them at the time. Finally went to Hoboken and spent four or five days there. They seem to think that the license for which they pay us Royalties covers only hyperbolic functions....and since the trigonometric scales were used before they owe us nothing on them. The only thing they were willing to do for us as you know is to guarantee us a minimum Royalty which is covered by the Supplementary contract we signed some four or five years ago. I consulted a lawyer at that time, one of our own Professors at the Law School. He told me.....we may sue them, with the chance of a long drawn out law suit and the possibility of losing not only what we are getting now but also trial costs. Hence, the question arises what can we do? They are aware of the fact that a poor Professor can not do much when they have a good legal department. Maybe they would look differently at the matter if you would write to them under the title "Chief Engineer". I do not mean this as a joke. I

mean it very seriously. If you have any suggestions regarding the matter, I shall be glad to hear them.” (Author’s note: There is no doubt from the sad tone of this letter that Weinbach had given up the battle with K&E. His reference to “Chief Engineer” is because Puchstein had left the University of Ohio and was working for the firm of Robbins & Myers, Inc., in Springfield, Ohio. At this point in time the file closes as the Archives do not contain any response from Puchstein to Weinbach’s letter).

Phase three, 1938-1939: Weinbach’s part in K&E’s introduction of the Log Log Duplex Vector Slide Rule, the K&E 4083.

This Phase actually started on a date in between his correspondence with Puchstein, and may be the reason Weinbach was reluctant to take any action against K&E. It began with a March 31, 1938 letter he wrote to C. M. Bernagau, V. P. and Treasurer of K&E. (Author’s insert: This letter was about a new idea Weinbach had. It was not about the K&E 4083 rule that we will find would first be mentioned in a later K&E letter on 5/13. Other than the Royalties that he had been receiving annually from the Company this appears to be the first written contact between them in over three years since the signing of the Supplemental Agreement in December 1934. By this letter Weinbach opened a long closed door. What now follows in this narrative is a significant portion of the correspondence found in the Archives between K&E and Weinbach from March, 1938 to January, 1940. It is important to present this in some completeness because the Archives offer a rare and unique historical record of the development of the new K&E 4083, Log Log Duplex Vector Slide Rule).

In his March 31st letter Weinbach said, “Several users of the Log Log Vector Slide Rule have asked at various times during the past few years whether a method could be devised for slide-rule addition and subtraction of vector quantities. With the rules you are making at present, including the Log Log Vector rule, these operations are affected by splitting up the several vectors into respective horizontal and vertical components. The addition and subtraction of these respective components must be carried out however in the usual manner since slide rules, as made at present, are not adapted for the fundamental operations of addition and subtraction”.

“I have recently devised an interesting and most excellent method by means of which the slide rules of the vector type including the Trig and Decitrig could be adapted for the above mentioned operations thus eliminating the mental operations of addition and subtraction. By this newly devised method these processes would be performed on the slide rule with the same facility as an ordinary slide rule multiplication. This method, which is fully Copyrighted, if embodied in the design of a slide rule of the Log Log Vector type, will make the rule unique in its completeness as a calculating tool in the hands of its user. Kindly let me know the extent of your interest in the matter.”

K&E responded with interest and asked for a copy of his Copyrighted article. On April 26, 1938 Weinbach mailed to K&E a six page instruction manual, dated February 15, 1938, with the title, “SLIDE-RULE, ADDITION AND SUBTRACTION of REAL, COMPLEX AND VECTOR QUANTITIES”. From the detail presented in this manual it is obvious that Weinbach must have been working on this for some length of time. In the accompanying letter summarizing the slide rule’s operations he asked K&E to “let me

know whether you are interested in these unique, interesting and useful improvements in the slide rule.”

On May 13, 1938 C. M. Bernagau, V. P. and Treasurer of K&E, wrote to Weinbach. This letter was a complete rejection of his ideas. Bernagau said that they had studied his Article and thanked him for a copy of the instructions, but went on to say that none of these ideas of a slide rule to be used for addition and subtraction of vectors was new to them. He then proceeded in some detail to point out to Weinbach a number of other already published articles regarding the use of the slide rule for vector addition and subtraction. (Author’s insert: This letter must have been a big disappointment to Weinbach as he had obviously spent a great deal of time and effort working on this idea. Reading K&E’s letter must have taken him back to ten years before, when on March 22, 1928 W. G. Keuffel, President of K&E, had rejected his original design of the Vector slide rule. Again, K&E was just not interested in his efforts).

However, the last paragraph of this letter was very interesting. What K&E proposed in it marked the real beginning of Phase 3. Here Bernagau said, “Referring to another subject, we have for some time been studying the Log Log Vector Rule with the idea of increasing its usefulness by the addition of scales LL1, LL00, and A, for which there have been requests from several sources. To make room for these scales will of necessity require the rearrangement and elimination of some of the scales at present on the rule. We will not go into detail at this time as we expect to have a sample rule ready within a few weeks at which time we will send it to you for criticism.” (Author’s insert: Although he must have been quite surprised and curious about this last paragraph, the Archive files show no answer from Weinbach to this K&E letter. He must have wondered, as time went by, as to when he would hear from them again. As it happened, over four months would go by until K&E would write).

On September 21, 1938, K. Keller, Vice President, sent a four page letter. He said, “We are sending you by Parcel Post a sample of the improved LOG LOG VECTOR Slide Rule to which we referred in our letter of May 13th. This rule is not perfect as it was necessary to insert a section of facing, but it will serve as a model. During the past few years we have been remodeling our line of high grade rules and believe it is advisable also to modernize the VECTOR, making it possible to broaden its usefulness without sacrificing its present functions. To make a comparison of the present LOG LOG VECTOR with the improved (which we will call the LOG LOG DUPLEX VECTOR) the locations of the scales on each rule are given in the following diagrams:”

LOG LOG VECTOR

Front side: || L, LL0, DF || CF, B, CI, C || D, LL3, LL2 ||
Back side: || SH1, SH2, TH || SI1, SI2, TI || D, S, T ||

LOG LOG DUPLEX VECTOR

Front side: || L, LL1, DF || CF, CIF, CI, C || D, LL3, LL2 ||
Back side: || LL00, LL0, A || B, T, ST, S || D, TH, SH2, SH1 ||

K&E went on in the letter to describe the changes that had been made. These were:

1. The scales added were: LL1, LLOO, A, and CIF.
2. The scales removed were: S and T on the lower body.
3. The scales which had names changed were: SI1 to ST; SI2 to S; TI to T.

4. The SH1, SH2, and TH scales had no change as they had only been moved from their upper to the lower position on the stock.

They explained that with the change in scales they will have to use a new method for the solutions of vector problems. The new method would use the S, T, and D scales, and only require one setting of the indicator hairline and two settings of the slide. Also, it had an advantage as it would never call for an extra shift of the slide index as the present method does. (Author's insert: This new vector method used the following right triangle formulas: $a/b = \tan A$, and $\sin A / a = \sin 90^\circ / c$. Then to be able to utilize the usual proportional features of the slide rule scales these two formulas would be rewritten as: $1/b = \tan A / a$, and $\sin A / a = 1 / c$, where 1 represents the left slide index on the rule. Then, given any two of the values, and using the left index on the slide, one could solve for the third value. For example, given a and b , one could solve for $\angle A$ or c).

Continuing the letter, Keller said, "The use of the hyperbolic scales will be the same as on the old rule but of course as adapted to the triangle solution method given above."

"Due to the elimination of the S and T scales on the body, solutions of triangles whose sides are expressed as sines or tangents will require the reading of the value of the sine or tangent by first flushing the rule and reading the value from S or T on the slide to D on the body. This slight disadvantage is the only one the new rule has."

"The addition of scales LL1, LL00, A, and CIF, the slanting numbers of the trigonometric scales, the erect instead of inverted trigonometric scales, all in proper relationship to one another whereby the solution of problems may be carried on in a logical, continuous manipulation, makes this rule with its hyperbolic scales a most complete instrument. Thus the position of the LOG LOG DUPLEX VECTOR should be maintained and even raised in importance in our modernized line of high grade Slide Rules."

"Although we are starting on a new lot of these LOG LOG DUPLEX VECTOR rules now, it will take until about next April to produce the initial lot and at that time we shall be pleased to send you a rule for your personal use. Kindly return the sample rule at your earliest convenience."

On October 11, 1938 Weinbach wrote to Keller. M.P.W. said, "I am returning to you by parcel post the sample Vector slide rule mailed to me some time ago. It was kept here somewhat longer than I anticipated. Quite a few of our staff in the College of Engineering examined and used it. The rearrangement of scales to permit additional ones is well done and has resulted obviously in greater usefulness. A few who examined it would like to have the T and S scales interchanged in position, possibly because they are used to the other model. Personally, I prefer the arrangement as you have it, because the S scale in conjunction with the D scale is used much more. Kindly let me know when you put it on sale, so that I may inform my students." (Author's insert: Weinbach had to be very pleased. With these new design changes he was finally getting his general purpose rule that he had written to K&E and Puchstein about so many years before).

The return letter from K&E to Weinbach was from the President, A. W. Keuffel. He wrote on October, 18th, "This will acknowledge receipt of the sample VECTOR rule which you returned to us on Oct. 17th. We are pleased to see that you and your staff are well pleased with the new model. We will let you know in ample time before they are placed on sale and as soon as we have a rule from the first production lot we will send it

to you with our compliments.” (Author’s insert: Weinbach was probably happy to see this exchange of letters, and with such a gracious response from K&E’s President after so much time had passed by). Pictures of the new K&E 4083 Slide Rule are in Appendix 5.

Three months later, on January 16, 1939, C. M. Bernagau, V. P. and Treasurer of K&E., sent a letter to M.P.W. informing him that the present rule, the Log Log Vector #4093, was selling faster than expected. K&E had estimated there would be sufficient stock to last to the end of April, but it now appeared they would run out of rules in early February. He told Weinbach that it then would be necessary to have a revised Manual for use with the new Vector Slide Rule. In the letter he said, “Therefore to expedite matters we have prepared a revised manuscript which we are sending you under separate cover in which we want you to feel free to make any changes which you think are in order. You will notice that the name and number of the rule have been changed from the Log Log Vector #4093 to the Log Log Duplex Vector #4083.”

“In place of the Log Log Duplex #4092 Manual which was furnished with the old rule along with your Log Log Vector #4093 Manual, we shall furnish with the new rule the Log Log Duplex Decitrig #4081 Manual together with your new Log Log Duplex Vector #4083 Manual. The #4081 Manual will apply perfectly to the revised rule, making it only necessary in your new Manual to explain the plane Vector calculations as applied to Electrical Engineering and the solution of problems involving hyperbolic functions.”

“In addition to the manuscript referred to above we are again sending you the sample Log Log Duplex Vector rule, which will be useful to you in preparing the problems, and also a copy of the Log Log Duplex Decitrig #4081 Manual which you may refer to in order to avoid including any matter in your Manual which is thoroughly covered in the #4081 Manual.” (Author’s insert: Weinbach must have been pleased to see the words “your manual”).

Weinbach answered on February 2, 1939. His letter to C.M.B. returned the manuscript with numerous changes. His comments on the more important of these were; “I replaced part of the introduction with some needed additional information pertaining to the ST scale. No substantial changes were made in the section on plane vectors. However, I reorganized this section into two parts properly designated so that that the reader could conveniently refer to them. Other minor changes or additions are marked clearly and are self-explanatory.”

“Several changes and corrections were made in Section II dealing with Hyperbolic sine and tangent scales, as indicated on pages 9 and 10. I have placed a completely rewritten Section under III covering Hyperbolic functions of complex numbers. I had to rewrite this material in full in order to include certain new situations that have appeared by virtue of the removal of the duplicate S and T scales, and also to give the user more definite information regarding the use of the scales as well as reasons for doing so.”

“You will note that I have added Section IV dealing with the slide rule calculation of inverse hyperbolic functions of complex numbers and included some illustrative examples as well as several illustrative applications. This Section IV is entirely new.”

“I have also added a table of contents for the user to conveniently find a particular reference to solve his problem. You will also note the changes I have suggested on the front cover. Puchstein has not been associated with the University of Ohio for the past eight or nine years. The propriety of associating his name in this new edition of the manual with this Institution is now questionable. The University might object, and it may

embarrass Mr. Puchstein. I trust you will be pleased with and approve of the various changes and additions.” (Author’s insert: Again, Weinbach had made a remarkably fast turnaround as it took only a few days for him to make substantial revisions in what K&E had sent to him. K&E benefited significantly from Weinbach’s changes as they resulted in almost a complete rewrite of the key portions of the Manual).

On February 21, 1939 A.W. Keuffel wrote enclosing a retyped copy of the manuscript for Weinbach’s review. This only included some suggested minor changes as K&E had accepted almost all of his revisions. A.W. Keuffel closed this letter with, “Our stock of the old Vector Manuals is now completely exhausted and unfortunately we shall have to fill the demand for Vector rules for the present without this Manual, keeping a record of shipments and sending the Manual out later when the new supply is ready. You will therefore realize how urgent it is for us to get out the Manual, and your prompt reply to this letter will greatly assist us in so doing. We take pleasure in presenting you with one of the new rules, which we are sending by parcel post today.”

Three days later, on February 24th, Weinbach answered K&E’s letter of the 21st. He said, “I received your letter of February 21 and the retyped copy of the instruction Manual just as I was to mail to you a list of corrections to be made in some of the illustrative examples and problems. The calculations as given on the original manuscript were made rather hastily as we were pressed for time. Some of our errors were also due to our unfamiliarity of the scale arrangement on the new rule. I am glad, therefore that these calculations were checked and necessary corrections were made.” (Author’s insert: In addition to these changes Weinbach made a few other minor corrections and comments, and then returned the revised and retyped copy of the instruction Manual to K&E. This was the last exchange of correspondence about the Manual. K&E accepted all of his changes, and then proceeded to prepare this final version of the Manual for printing. Unfortunately, the new K&E 4083-3 rule that K&E sent to Weinbach was not found in his personal belongings and is lost).

On May 8, 1939 Weinbach asked K&E to mail him four copies of the Manual, when ready, for their University of Missouri-Columbia Engineering Library.

C. M. Bernagau sent a letter to M.P.W. on May 11th saying they would expect to send the four copies of the Manual not later than the middle of June. C.M.B. also discussed a twenty inch rule by saying, “We find that the manufacturing cost of the improved twenty inch LOG LOG DUPLEX VECTOR Slide Rule, # 4083-5, will permit us to make a reduction in the list price of this rule from \$35 to \$30. This cost reduction is due to the fact that the new arrangement of scales is more readily adaptable to our equipment than was the case with the old arrangement. We believe that this price change would increase the sales of the twenty inch rules sufficiently to be of advantage also to you, notwithstanding the fact that it would reduce your Royalty per rule, as according to our agreement we would pay you 5% Royalty on the list price of the rule. Please advise us whether the proposed change has your approval. The price of the ten inch rule is to remain unchanged at \$13.”

Weinbach answered on May 29th saying “the proposed change in the price of the #4085-5 slide rule meets with my approval.”

Then on June 28, 1939, A. W. Keuffel wrote , “As you requested, we are sending you enclosed four of the Manuals for the Log Log Duplex Vector Slide Rule #4083, which we are happy to say is finally ‘*off the press*’. We trust you will find this booklet satisfactory.”

Next, on July 12th, A. W. K. wrote again saying, “Will you please give us your full name, which we require for filing the Copyright of the Log Log Duplex Vector book. All we can find in our records are your initials, ‘M. P.’. It is also required when applying for a Copyright to advise of citizenship and we would appreciate a statement from you that you are a citizen.” (Author’s insert: Professor Weinbach must not have smiled when he read this letter from A. W. Keuffel. Could it be that after all of these eleven years they did not know his first name? Had they forgotten that he had applied for his own Copyrights in the past? The act of doing this would show K&E that he was a citizen. They should have known this.).

The next letter from K&E was from A. W. Keuffel on September 14th. This informed M. P. W. that they would soon have to reprint the #4083 Manual and wondered if he had any suggestions or corrections to offer for the reprint. Also, they were interested as to how the revised Vector rule was working out.

Weinbach answered on October 9th saying that after checking he had found one or two typographical errors. Also, he would like to add further instructions to the manual covering the calculation of the square root of the difference between numbers. Last, he said that from comments he had received the new rule was going over quite well.

A.W.K. writing back on October 23rd asked Weinbach to please send the typographical errors as promptly as possible as they find the supply of Manuals is very low and they must make a reprint soon. K&E said that as far as adding new material to the Manual this would be very inconvenient at this time and they only want the typographical changes to be included in the reprint.

Two days later on October 25th Weinbach sent the following corrections:

1. First line, first paragraph, page 2; Aej^0 , should be Ae^{j0} .
 2. The same correction should be made in the first line following (B), page 4.
 3. The third equation preceding (B), page 30, that reads $+j\theta$, should read $x + j\theta$.
- (Author’s insert: These error corrections are remarkably few when one considers the very short time Weinbach had to revise the manuscript for the Manual. In spite of this he obviously did a very exceptional job.).

Then on January 10, 1940, A. W. Keuffel wrote, “We are sending you under separate cover several copies of the reprinted Log Log Duplex Vector Instruction Manual. If you have use for anymore, we will be glad to send them to you if you will let us know.”

This last letter concludes Phase 3 of this Article. During this time it appears that K&E and Weinbach had settled their past differences. Relations were positive and K&E must have been very satisfied with Weinbach’s contributions, for which they gave him full credit as Author of the K&E 4083 Manual. A picture of the cover of the K&E 4083 Slide Rule Manual is in Appendix 6.

With the closing of Phase 3 on January 10, 1940 another big gap of almost four years occurs in the Archive files. There is no correspondence for the balance of 1940, and for the years 1941, 1942 and 1943. The only communications in those years were the annual

Royalty payments that Weinbach received from K&E. As the amount of these Royalties over the years may be of interest, a listing of these is shown in Appendix 7. Unfortunately K&E never furnished any details as to the number of slide rules sold when they mailed the Royalty check each year. So, the numbers of slide rules sold each year, as shown in Appendix 7, are estimates derived from the total of the amounts of the annual Royalty payments.

K&E's original model numbers were 4083-3 for the ten inch rule, and 4083-5 for the 20 inch rule. In years following 1939, K&E made a number of changes in the scales and in the model numbers. The last of these was in 1962. None of these involved fundamental revisions in the operations of the rule. A brief listing of these changes follows in Appendix 8.

Phase four, 1944-1946: Weinbach initiates litigation against K&E.

On March 5, 1944, a little over four years since his last letter to K&E, Weinbach wrote to C. M. Bernagau, former V.P. and Treasurer, who was now President. In it he described two unusual visits he had received that he felt K&E should know about. He said, "I had in my office a few days ago two gentlemen who seemed very much interested in slide rules. One of these paid me a visit about two months ago. He had at that time a most complete and interesting assortment of ordinary and special purpose slide-rules of all makes and periods. He seemed to be amazingly familiar not only with the use of slide-rules in various branches of the engineering profession but also with the manufacturing processes."

"This time they had copies of all sorts of patent papers on calculating devices including slide-rules. They came to me, they said, as author of your instruction book on vector calculations, to obtain the details of my obligations to you as designer of the vector rule. I showed them the agreements, and with my permission they made copies of them to submit to competent legal study and interpretation. I told them, however, that although not stated in the documents, you do not claim the protection of my copyright for the decimally-divided trigonometric scales when these scales are not together with the hyperbolic scales. I further told them that although not explicitly stated, you do not intend to claim the protection of my copyright for the hyperbolic scales when with or without the decimally-divided trigonometric scales after December 31, 1947."

"I am reporting this to you because of my sincere desire to act entirely within the limits of my obligations as circumscribed by the contracts. Your advice on the correctness of the statements above will be therefore appreciated." (Author's insert: Professor Weinbach said in his notes that the names of these two gentlemen were, Camille LeClaire and Don C. Woodman. He did not know who they represented. When he asked them, they said they would inform him in due time – but, they never did. They were so knowledgeable about the workings and manufacturing details of slide rules that the Professor said he thought they worked for K&E. The Author has tried to obtain some information about them but has not been successful. As we will see later, from K&E's reaction to Weinbach's letter, these gentlemen obviously did not work for them. Speculating, I think they may have been representing Pickett and Eckel, or Dietzgen. Both of these companies introduced Vector slide rules in 1948. With Weinbach's Copyright expiring in 1947 this

could have been about the time they would have been doing their preliminary research towards the goal of manufacturing a slide rule with hyperbolic scales).

Bernagau replied on March 8th, “We thank you for your letter of March 5 regarding our slide rule agreements. As you realize it is many years ago since we went into this matter in detail and it is therefore necessary for us to look into our records and refresh our recollection of the understandings which we then had. After we have had an opportunity to do this you shall hear from us further.”

Almost four months would pass until Weinbach would hear again from K&E.

The surprise visit from the two gentlemen must have stirred up distant memories in Weinbach’s mind about his past troubles with K&E. A short while after sending the March 5th letter, Weinbach happened to run into his old friend, Dean Harvey, who was visiting in Columbia for a few days. Harvey, a close friend for many years, was a Patent Attorney. He had recently joined the Chicago firm of Carlson, Pitzner, Hubbard & Wolfe, and was in the process of moving his family to Chicago. In their meetings Weinbach related his past dealings with K&E, and out of these discussions the thought of bringing a suit against K&E for the loss of past Royalties was raised. After returning to Chicago, Harvey wrote to Weinbach asking for all the pertinent information he could send about dealings with K&E, and the relations with Puchstein.

On May 31, 1944 Weinbach answered Harvey, sending to him “the write-up of my dealings with the Keuffel and Esser Co., all of the correspondence pertinent to the subject I had with them, and my contracts with the company, arranged in chronological order.” (Author’s insert: This was a complete package. The “write-up” was 26 pages long. It was a well balanced and an excellent summary covering all of the history with K&E and Puchstein. This covered the entire period from 1928 up to the 1944 meeting with the two gentlemen).

Harvey asked, Richard Russell Wolfe, a Partner in the firm to review the file. On June 20, 1944 Wolfe wrote to Weinbach saying, “In going over this material, I did so with the purpose of ascertaining whether or not there was on the face of the matter sufficient likelihood of recovery against Keuffel & Esser to make a thoroughgoing study and opinion worthwhile. My conclusion on that point is that the probabilities are sufficiently good that an action can be successfully maintained against Keuffel & Esser by reason of their manufacture and sale of the Log Log Decitrig to warrant making a complete investigation.” Wolfe’s letter then went on for some length explaining how they would investigate the possibilities of a course of action involving both breach of contract and copyright infringement. As to cost Wolfe said, “If you wish us to undertake the investigation recommended, we can then give you a reasonably well-founded opinion as to whether or not a suit should be filed. I presume that you would like to have some estimate of the cost..... I think it will run between \$150 and \$200.”

On June 21st, Dean Harvey, who was then out of town on a case, wrote a hand written letter to Weinbach saying that he knew Wolfe, who was the firm’s trial expert with long experience, had written the day before. (Author’s insert: Harvey, while out on a case, wrote more than one hand written letter to Weinbach during the months of June – August.

They were close friends and all of the letters were started with the salutation “Dear Weinie”. I smiled each time I read this, as with that beginning these letters truly had to be from friend to friend). Harvey went on to say that he and Wolfe had discussed the matter at length, and he wanted Weinbach to know what might happen if he were to decide to go ahead with a suit. Harvey pointed out that Keuffel & Esser would in all probability stop the payment of Royalties. In that regard, Harvey advised Weinbach to contact Puchstein about the current discussions as he would necessarily have to become a party plaintiff to the suit. As such Puchstein would also lose his Royalties.

As the correspondence between Weinbach, Harvey and Wolfe was taking place we now find that after four months K&E would finally reply to Weinbach’s March 5th letter. On June 30, 1944, K&E President, Bernagau, wrote to Weinbach saying, “Because of the press of current work, it was impossible for any of us here who had been directly connected with your matters to review the record, and since some of the questions which you raise in your letter of March 5, 1944 related to copyright and patent rights, we referred your letter to our counsel for study and received a report from him including the following:

‘In 1934 Professor Weinbach raised a question with respect to a new rule which Keuffel & Esser Company had recently put on the market and after various negotiations a Supplemental Agreement was entered into dated December 18, 1934 which includes the following covenant:

‘The parties of the first part (Weinbach and Puchstein) shall use every reasonable effort to promote the sales of slide rules manufactured by the party of the second part and to promote the good will associated with KEUFFEL & ESSER COMPANY, and such promotion is the essence of this agreement’.

The letter from K&E’s counsel went on to say,

‘Under the original agreement of September 5, 1929 it was agreed:

First: That the parties of the first part (Weinbach and Puchstein) grants unto the party of the second part, during the life of said patent No. 1,487,805 and copyright 15998 Class 1, XXC, the sole license to manufacture and sell rules embodying the said patent and copyright, and including all modifications and improvements of which said design is susceptible and which hereafter may be made by either party’.

Then counsel continued with these comments:

‘Professor Weinbach’s letter of March 5 reports actions on his part evidently in violation of the agreement which K&E entered into with him and also the development of a situation that apparently will require steps to be taken to enforce the sole rights which were granted in this matter. Under these circumstances it appears necessary and advisable that future royalty payments be placed in reserve so that they would be available to enforce for the full term the sole rights granted to K&E under the above identified contract.’

After reciting the above report from their counsel, Bernagau ended the June 30th letter by saying, “We assume that, because of your sincere desire to act entirely within the limits of your obligation, you would not intentionally have done anything which would in any manner be contrary to our interests. There must be some explanation for the action on your part which gives rise to the conclusions drawn by our counsel and we feel that you would welcome an opportunity to clarify this situation.”

(Author's insert: Weinbach must have been stunned by this letter from Bernagau. I am sure that he never dreamed he would receive such a response from K&E. Where he thought he had reported the meeting that took place in good faith, he now found that K&E's counsel considered he had acted in bad faith. Further, after K&E's counsel had reviewed the past agreements, Weinbach was told he really had no rights at all under his Copyright. A further serious blow was the high probability that the annual Royalty payments were going to be withheld. In 1943, his share alone of the Royalty payments was \$2,914.38. At that time University Professors probably made from \$4,000-\$5,000 annual salary, so the Royalties were a significant addition to his income for the year).

There is no letter in the Archives from Weinbach to K&E in reply to their June 30th letter. Instead, we know that in the interim Weinbach had consulted counsel of his own, and in time his counsel would answer K&E. (Author's insert: All of these events taking place during this same time period have to be considered an amazing coincidence. First, Weinbach's surprise visit from the two gentlemen. Second, Weinbach's letter to K&E about this visit. Third, the chance meeting of Weinbach and Harvey, and their following discussions. Fourth, Wolfe's review of the file and his recommendation to proceed with the investigation. Then we find the Third and Fourth events had occurred before and without knowledge of the last event that was K&E's letter of June 30th to Weinbach).

On July 6, 1944 Weinbach wrote a long letter to Wolfe. With this was enclosed K&E's letter of June 30th. Weinbach had this to say about this new development:

"In a note received a few days ago from my good friend, Dean Harvey, he cautions me that should we start some action against the K&E Co. they would in all probability stop payments on royalties. The enclosed letter from the K&E Co. received yesterday in reply to mine of March 5shows what Harvey thought might be a probability is an actuality even without any definite provocation on my part."

"In good faith, I felt obliged to inform them of my conversation with the two gentlemen who visited me sometime in March. One of them came to see me before and I thought at that time he was a K&E representative. I have not seen either of the two since last March. I have no idea who they represent. When I asked them, they said they would inform me in due time. They seemed to be familiar with slide-rule use and manufacture, and were familiar with the fact that the Puchstein patent expired in 1941, and wanted to know what my obligations to the K&E Co. are. It never occurred to me that it is a criminal action or illegal, or a breach of contract to tell to a third person or persons about one's contractual obligations. So I told these gentlemen that since K&E Co. do not pay any royalties on the use of my copyrighted trigonometric scales on their decitrig rules, they of course cannot expect any protection offered by my copyright. I further told them that by a supplementary contract they do not intend to pay any royalties on the copyrighted scales after December 31, 1947. I suppose that protection offered by my copyright would presumably cease on that date."

"In my letter of March 5, to the K&E Co. I informed them in good faith of this conversation and asked them to tell me whether the above is a correct interpretation of my contractual obligations to them. Instead of giving a direct answer to my question either one way or the other, they avoid committing themselves, take an offensive attitude and accuse me of violating the contract. They always take this offensive attitude whenever their obligations to me are questioned. They take it for granted that I have no

counsel, and will thus scare me into submission. I shall appreciate your advise regarding this new turn in my relations with K&E Co.”

In addition to the above, Weinbach’s July 6 letter included questions and comments on two other subjects. The first of these had to do with the investigation and costs of a suit where he said, “On the supposition that such an investigation does indicate the possibility of a successful suit, what about the cost of such suit? Could that be provisional or contingent? I am not quite certain that these are the correct or proper terms, but I have no doubt that you know what I mean.”

The second answered a question Wolfe had of how many decitrig slide rules might have been sold by K&E in the eleven years between 1933 and 1943. Weinbach uses about a page and one-half in the letter making calculations and constructing a table that shows the estimated number of decitrig slide rules sold at 298,790 (rounded to 300,000).

On July 14th, Wolfe answered Weinbach saying in reference to K&E’s June 30th letter, “Keuffel & Esser’s latest move in the matter seems very high-handed indeed. Your good faith in the matter throughout is quite obvious.”

Weinbach’s close friend, Dean Harvey, telephoned on August 8th, and then followed up with a hand written note on the same date. Harvey wanted to report that he was going to open his own office in St. Louis. He was planning to be associated with the firm Kingsland, Rogers, and Ezell, and at the same time maintain his own practice. Harvey would be in Columbia on Friday the 11th, and over the weekend of the 12th and 13th. He would call as soon as he arrived so that the two of them could meet to discuss how to proceed. (Author’s insert: This change in firms would have little effect on the status of the case. From the beginning Harvey had taken the lead behind the scenes. He had been working continuously on the case and had completed a large part of the law search. It would be of definite advantage for Weinbach to have both Harvey and the services of the new firm, Kingsland, Rogers, and Ezell, on his side. There is no record in the Archives of Weinbach’s and Harvey’s meeting that weekend, but we know that from the following events the Professor decided to turn matters over to his old friend).

Next in the file are two letters dated August 19, 1944 from Dean A. Harvey, Attorney-At-Law, St. Louis, Missouri, to two New York law firms. (These are written on Harvey’s new letterhead as Attorney-at-Law and Registered Professional Engineer; practicing in Patents, Trade-Marks, Copyrights, and Unfair Trade Practice). They read as follows: “I am presently considering a matter which involves an infringement of a copyright by the registrant’s licensee, and have seen fit to recommend to my client, the registrant, that he consider retaining Eastern counsel for the trial work in the event a suit is filed. I have suggested to him the names of several men with whom I have become acquainted, and I am writing to you, as one of these men, to ascertain the basis upon which you accept cases for trial and the charges for your services. In order that you may early determine whether a conflict of clients would prevent you from taking the case, the defendant will be the Keuffel & Esser, Company, of Hoboken, New Jersey. The amount of the claim involved is estimated at approximately \$180,000 which represents unpaid royalties over a period of some ten or eleven years.” (Authors insert: I made a calculation in order to find out from where this figure may have originated. From Weinbach’s July

6th letter I took the table showing the yearly estimated sales of the number of decitrig slide rules, and then calculated the royalties using the prices shown in the yearly price lists in Clark McCoy's web site of K&E Catalogs. The estimated total of royalties ranged from \$182,000 to \$197,000, the difference depending on which slide rule case was ordered with the rule; the Morocco or the Leather. This result is remarkably close to the claim of \$180,000 in Harvey's letter).

One of Attorney Harvey's letters would be successful in securing Eastern local counsel. This was, George D. Richards, Counselor at Law, of Newark, New Jersey; practicing in Patents, Trade-Marks and Copyrights. The K&E offices were nearby in Hoboken, N.J. As the case progressed, Dean Harvey would supply Richards with originals of all of the papers to file. Richards' role as local counsel would be to properly present these to the court.

In the remaining days of August and into September, Dean Harvey had a number of discussions with Weinbach, and Lawrence Kingsland and Edmund C. Rogers, of the firm. On September 28, 1944 Harvey wrote Weinbach saying that Colonel Kingsland, Mr. Rogers, and Harvey had just finished four days of conferences and all agreed that the cause was actionable. Colonel Kingsland had authorized Harvey to state that the Colonel would be willing to join with him in the prosecution of the case on a contingent basis. An estimate of bringing the suit in the Eastern District Court would probably cost Weinbach between \$1,500 and \$2,000, and the Professor should be prepared to meet expenses to that amount. The three of them would like to meet with him in St. Louis at an early date after October 16th. Let them know what date would be best for him.

On October 4th Weinbach replied saying, "My duties have been rather heavy for the past two weeks, since the fall term of the University started on September 23. As you know, I am the only one left in the Electrical Engineering Department. This will explain in part this delayed reply to your letter of September 28." (Author's insert: Remember Reader that we are about one year away from the ending of World War II, and that Weinbach's colleagues were either in uniform or working somewhere in a government laboratory). Weinbach said that he would let them know when he could meet with them in St. Louis. In another letter a few days later he confirmed October 27th as the date.

The four of them, Weinbach, Harvey, Kingsland, and Rogers met in St. Louis on October 27, 1944, and decided to proceed with the suit against K&E. The attorneys agreed to work on a contingent fee basis.

The next day, October 28th, Weinbach wrote to Puchstein to inform him about the events of the past few months. The letter related the visit of the two gentlemen, Weinbach's letter to K&E, and K&E's response. In reference to the latter Weinbach said, "The enclosed copy of their letter dated June 30, 1944, indicates that instead of giving me a direct answer, they took, as they always did, an offensive attitude. They accuse me of violating the contract, and as a consequence have decided as a punitive measure to suspend payments of future royalties. I do not know if they mean your royalties, also."

"This arbitrary action on their part, coupled with their refusal to give me a direct answer, caused me to decide to turn the matter over to a reputable firm of patent attorneys in St. Louis for study and report. At a conference with them last Friday, October 27, they came to the conclusion that there is sufficient cause for a law suit on breach of contract

and a possible 50-50 chance. They are willing to prosecute our claim in a contingent fee basis, and that I pay all the necessary expenses involved.”

“They advised me to inform you of the situation, and ask you, as a party to the original contracts, to include your name in the litigation. In such a case you will have to authorize me to engage legal counsel.”

“In the judgment of my attorneys, the expense of the litigation will probably range between \$1500 and \$2000. This includes the employment of local counsel, traveling expenses, cost of depositions, etc.”

“Expecting to hear from you soon regarding this matter, I remain with personal regards....”

Also, Harvey on October 28th mailed Weinbach the draft of an “Agreement” between the two of them. In this Weinbach appointed Harvey, and the firm of Kingsland, Rogers, and Ezell, co-counsel, as his attorney to prosecute by litigation or settlement a cause of action against Keuffel and Esser Company. In consideration of the legal services counsel is to perform they will be paid a fee contingent upon any sum recovered. The fee will be 40% of the first \$50,000 recovered; plus, 33 1/3% of any fees recovered above \$50,000. Harvey would have authority to employ associate counsel. However, the fee provided would be the entire fee to be paid for all legal counsel combined. Weinbach would be responsible for paying court costs and expenses. This agreement was signed on 10/28/1944 by Harvey and on 10/31/1944 by Weinbach.

On November 17th, Harvey wrote Weinbach informing him that they had received a letter dated 11/15 from Mr. Puchstein giving authority to prosecute the case. Harvey said, “With this authority we are proceeding to draw up the Bill of Complaint and will file suit as soon as Colonel Kingsland returns from Chicago, which will be sometime next week.”

Harvey sent George Richards, in Newark, copies of the Complaint on December 7, 1944, saying, “This will transmit to you three copies of our Complaint, which is to be filed in the Keuffel and Esser case.....” In December 1944, Civil Action No. 4307 was filed in the District Court of the United States for the District of New Jersey. Plaintiffs were M.P. Weinbach and A.F. Puchstein; Defendant was Keuffel and Esser Company. The amount of damages claimed by Professors Weinbach and Puchstein was \$300,000.00. A copy of the Complaint follows:

DISTRICT COURT OF THE UNITED STATES
FOR THE DISTRICT OF NEW JERSEY

M. P. Weinbach	:		
A. F. Puchstein	:		
Plaintiffs,	:	Civil Action No. <u>4307</u>	
v.	:		
	:		
	:	COMPLAINT	
Keuffel and Esser Company	:		
Defendant	:		

1.

The plaintiffs, M. P. Weinbach and A. F. Puchstein, are citizens of the State of Missouri and the State of Ohio, respectively, and the defendant is a corporation incorporated under the laws of the State of New Jersey. The matter in controversy exceeds, exclusive of interests and costs, the sum of \$3,000.00.

2.

On or about September 5, 1929, plaintiffs and defendant, for a valuable consideration, entered into a contract in writing, a copy of which is attached hereto as Exhibit A, wherein and whereby defendant agreed to pay to the plaintiffs certain moneys in the form of royalties for grants made under the terms of said contract.

3.

On or about December 18, 1934, plaintiffs and defendant, entered into a supplemental contract in writing, a copy of which is attached hereto as Exhibit B, wherein and whereby defendant agreed to pay to the plaintiffs certain minimum royalties and whereby the plaintiffs and defendant fixed a time after which no more royalties would be payable under the contract of September 5, 1929.

4.

Plaintiffs have duly performed all the conditions required by the terms of the aforementioned contracts on their part.

5.

Defendant has manufactured and sold slide rules coming under the terms of the aforementioned contracts without paying to the plaintiffs the royalties due thereon.

6.

Defendant has failed and neglected to perform the conditions of the contracts on its part in that it has failed to make annual accountings to the plaintiffs as expressly provided for in the contract dated September 5, 1929.

7.

Defendant, without cause, has threatened to impound and withhold all future royalty payments due under the terms of the aforementioned contracts.

8.

By reason of the foregoing facts, plaintiffs have been damaged in the sum of \$300,000.00.

WHEREBY, plaintiffs demand judgment in the sum of \$300,000.00, with interest, and the costs of this action.

Kingsland, Rogers, and Ezell

George D. Richards
Resident Attorney
605 Broad Street
Newark 2, New Jersey

By _____
Lawrence C. Kingsland

Edmund C Rogers
Members of above firm
705 Olive Street
St. Louis 1, Missouri

Dean A. Harvey
705 Olive Street
St. Louis 1, Missouri

Attorneys for the Plaintiffs

(Author's insert: In the year 1944 this claim would be considered a very large amount. In 2007 dollars it would be about \$3.5 million. The filing of this suit must have

caused a real jolt to K&E. I can only guess how a figure of \$300,000 was chosen for the damages. If we assume the suit was successful the \$300,000 judgment would be divided three ways. The attorneys would receive about \$103,000, and then that would leave \$197,000 for Weinbach and Puchstein to split. Now, \$197,000 was the high range of the lost royalties I calculated above when discussing Harvey's letters of August 19, 1944. So, if the plan was to restore the amount of lost royalties to the two Professors this may have been the way the total of \$300,000 was determined).

The lead attorney for K&E was the firm of Pennie, Davis, Marvin and Edmonds, 247 Park Avenue, New York City. They were represented by firm member, Curt Von Boetticher, Jr. K&E's local attorney was Young, Shanley & Foehl, 810 Broad Street, Newark, New Jersey.

It is beyond the scope of this Article to present the legal arguments and motions presented by both sides in preparation for trial. Actually, Professor Weinbach only had part of the file as all of the K&E motions and pleadings before the court went to his attorney, Dean Harvey. Now, Weinbach was kept abreast of progress through periodic reports from Harvey. So there is a fairly good record of what transpired during the sixteen months that the legal skirmishing went on. The following synopsis covers the events and highlights of that period that ran from December 1944 – May 1946.

December 1944: The Complaint is filed with the U.S. District court and served on K&E.

February 1945: K&E's attorney's answered the Complaint. K&E denied all allegations and claimed Plaintiffs aided and assisted competitors in violation and breach of agreements. K&E asked that the Complaint be dismissed with costs.

(Author's insert: During this time, on February 17, 1945, Professor Weinbach suffered a great personal loss when his beloved wife, Regina Paves Weinbach, died. They had been married for 37 years. The story of how they met was related to me by his Grandson, Richard Kershenbaum. It seems she came to the St. Louis World Fair in 1904 with a group from Romania. Born in 1883, she would have been 21 years of age. At that time Weinbach was 23, and a student at the University of Missouri in Columbia. When he heard there were some girls from his home country he traveled to St. Louis and while there met Regina. She stayed on and never returned to Romania. They were married sometime around 1907-1908. Probably after Weinbach became an Instructor in Electrical Engineering at the University in 1907.

The death of Regina was not his only set back during these months. He had been in general ill health for some time. Harvey, in a letter to him dated, May 21, 1945, said, "I hope this finds you back home and at work, since I know you are anxious to get back to your students." On June 6th Harvey writes, "It was good to hear you are recovering rapidly and that you have returned to your office." Again, Harvey, in a July 3rd letter says, "This will bring you up to date on the events which have occurred since you were here in the hospital." So, we find that sometime in the Spring months of 1945, Weinbach was ill enough to be hospitalized in St. Louis, and away from the University."

I will now go back and continue with the listing of the legal motions that were filed during and after that period of time).

February 1945: K&E's attorneys filed a list of Interrogatories for the Plaintiffs to answer.

March 1945: Plaintiffs answered K&E's Interrogatories.

March 1945: Plaintiff's attorney's filed a list of Interrogatories for K&E to answer. In the list was Interrogatory 14, in which K&E was asked to list all of the slide rules manufactured in the years 1929 – 1944. This asked for a detailed tabulation by numbers and dollar amounts of sales for these years.

April 1945: K&E introduced a motion before the court to strike Plaintiffs Interrogatory 14. K&E's reasoning was that this would give away business trade secrets to competitors. Plaintiffs argued that this information was needed in order to determine the correct amount of damages. The judge ruled in favor of the Plaintiffs.

May 1945: K&E balked at furnishing information required under Interrogatory 14. So, Plaintiff's attorney's filed a motion asking the Court to require K&E to furnish the tabulation.

June 1945: Judge ruled in favor of Plaintiffs and gave K&E sixty days to comply by furnishing the listing.

July 1945: Defendant's attorneys filed motions raising a Statute of Limitations issue, and a request to separate the issues of liability and damages for trial. This later motion asked for the issue of the question of liability to be separated from the issue of the amount of damages. So, there would be two trials. The motion was set for hearing in August.

Then on July 3rd Harvey wrote to Weinbach to bring him up to date on this request to separate the issues. Harvey says, "All of this useless procedure is, of course, intended to place you at as great an expense possible in hopes that it will eventually discourage you and cause you to abandon suit."

In July there was an exchange of letters between the Plaintiff's and Defendant's attorneys. This exchange was based upon a mutual understanding they had reached that as a matter of procedure the Judge will approve the motion for separation. Harvey, in an effort to avoid further stalling by K&E's attorneys and move things along, agreed to the separation. Then on July 30th Harvey wrote to Weinbach saying, "..... we have signed a stipulation reading as follows in which we agree to the separation of the issues of the case for trial:

1. The issue of the defendant's liability to pay royalties, under the contracts, Exhibits A and B, annexed to the complaint, and the issue as to the period of time for such royalties, if any, are payable, shall be tried as separate issues, under the provisions, of Rule 42(b) of the Federal Rules of Civil Procedure, prior to the trial of the issue of the amount of plaintiff's damages, if it be determined that plaintiffs are entitled to damages.
2. The issue of the amount of damages, if liability is found, shall be tried by the Court, both parties waiving any right to ask for the appointment of a special master.
3. Defendant's answer to plaintiff's interrogatory number 14 directed to be made under the order of this Court dated June 11, 1945, and all proceedings on the part of the plaintiffs for discovery on the issue of damages shall be stayed

until further order of the Court after hearing and determination of the issue of liability provided for in paragraph 1 herof.”

Harvey continued with this letter by telling the Professor that the next step was to arrange a date for him and Puchstein to come to St. Louis. The purpose of this was for the taking of their pre-trial depositions by K&E’s attorney, Von Boetticher.

Weinbach could not have been happy when he read Harvey’s letter of the 30th. K&E got everything they wanted, with separate trials that would double the expense and drag out the time. On August 4th he wrote a long letter to Puchstein bringing him to date on the recent events.

Throughout the month of August a number of letters went back and forth for the purpose of arranging a mutually suitable date for the taking of the two depositions. Finally, September 12th was selected as the date for the depositions. Both Weinbach and Puchstein, together with their attorneys, met in St. Louis on the 11th. The next day the depositions were taken by K&E’s attorney. A copy of Weinbach’s is in the Archive’s file. It is 53 pages long and covers a very complete examination by K&E’s attorney of the history between the parties. I read it and there were no new disclosures that had not been covered elsewhere in this Article. There is no copy of Puchstein’s deposition in the file.

After the St. Louis meetings Weinbach returned to Columbia for the start of the new school year. On September 25th he wrote Harvey saying, “We have been pretty busy the last few days with registration in all of the divisions of the University. The enrollment in the College of Engineering as of Monday September 23, is 335 which is more than three times as many as we had last year! Classes started yesterday and we shall gradually adjust ourselves again to routine.” (Author’s insert: He is, of course, referring to the beginnings of the influx of G.I. Bill veterans returning after the end of World War II. This brought back old memories for me as, at the same time those many years ago, I was one of the returning veterans starting Engineering classes at the University of Washington).

Unfortunately, after September 1945 the Archive records contain no further entries about the status of the suit. As the month after month passed by waiting for a Court date we can only wonder about Professor Weinbach’s spirits and frame of mind. Was he worried about the costs as time went by? Was he becoming more concerned about the outcome? Was his health deteriorating? We can only guess at the sequence of events during those ensuing months that resulted in an outcome.

Whatever took place we know that the suit never went to trial. In fact, Civil Action No. 4307 was dismissed on May 3, 1946. The Author was able to obtain a copy of the Dismissal from The National Archives and Records Administration (New York Office). The *STIPULATION OF DISMISSAL* reads: “IT IS HEREBY STIPULATED AND AGREED that the above entitled action be and the same hereby dismissed under the provisions of Rule 41 (a) (1) of the Rules of Civil Procedure without costs to either party against the other.”

So, we can assume from this dismissal that some kind of settlement did take place. Here the Author’s research runs dry. In spite of efforts to locate such, there are no Court or Archive records remaining as to the exact amount of this settlement. In correspondence

with Professor Weinbach's grandson, Richard Kershenbaum, he said, "My mother did talk to me about the K&E lawsuit, but not in any great detail. However, I do remember her saying that the case ended in a one-time cash settlement. The figure I remember is \$10,000. I think there was a feeling that K&E had exploited my grandfather's work, and tried hard to avoid compensating him fairly."

Now the breakdown of any settlement would have been 40% to the attorneys, 48% (60% x 80%) to Weinbach, and 12% (60% x 20%) to Puchstein. If \$10,000 represented Weinbach's share then the gross settlement had to be somewhere around \$20,833. However, this is just a guess and we need something more concrete on which to estimate the settlement amount. We are lucky as we do find a source in the Archives to help us estimate what the settlement might have been. This comes from a note penned by Harvey at the bottom of the October 28, 1944 Agreement between Weinbach and him. This note signed by Harvey and dated May 31, 1946, says, "All obligations arising under this contract have been completely discharged by the party Weinbach upon the payment of \$7,000.00 cash in hand, the receipt of which is hereby acknowledged." Now, Harvey was to receive 40%, so this would mean the settlement would have been \$17,500 ($\$17,500 \times 40\% = \$7,000$). Then Weinbach would have received \$8,400 (48%) and Puchstein \$2,100 (12%). (Author's insert: My feeling is that the settlement was \$20,000, and not \$17,500. This would mean Harvey would have voluntarily taken only \$7,000, with \$10,400 going to Weinbach, and \$2,600 for Puchstein. This way Harvey could help Weinbach receive some reimbursement for some of the expenses the Professor had paid. Of course the \$20,000 distributed this way is also just a guess, as we may never know the exact amount of the settlement and how it was divided. However, we can be reasonably sure it was only in the range of \$17,500 to \$20,000. This is a pittance compared to the \$300,000 originally claimed as damages in the suit).

Author's Summary and Comments

The record recited above speaks for itself. Therefore the Author feels somewhat presumptuous in attempting to summarize and comment on these events. So, my remarks will be brief.

I have tried in this Article to present a complete and balanced picture of the correspondence between the three parties. From what has been presented the Reader may have formed his or her opinion as to what position would have been upheld at a trial. The Author's sympathies lie with Weinbach and Puchstein. It is my hope that if the suit had gone to trial, they would have prevailed. Of course, the Author is not an Attorney, so someone versed in the Law may conclude that K&E should have been successful. The Author would appreciate feedback from Reader's as to what they think would have happened.

Following are some of the Author's comments regarding the four Phases:

Phase 1: We saw in Phase 1 how Professor Weinbach overcame K&E's reticence and almost single handedly developed the Log Log Vector K&E 4093 Slide Rule, and its Instruction Manual. He recommended its name as the "Log Log Vector", and more than once had to insist that the trig scales be in decimal format. While reading through the correspondence that covered Phase 1 the Author gained the distinct impression that K&E

had no real understanding of what Weinbach had accomplished. In fact there is a question as to whether they ever did appreciate or realize the historical importance of his slide rule design for solving complex hyperbolic functions by slide rule.

Phase 2: This becomes more obvious in Phase 2 where K&E shows no apparent knowledge of the fine points that Professor Weinbach is discussing. They raise smoke screens based upon previous designs of slide rules that had little to do with what he claimed were the issues. If K&E had just communicated in advance to him the plans they had to introduce the Log Log Decitrig Slide Rule they probably could have avoided most of the problems he raised with them. They handled their responses to his claims badly and the Professor felt cheated. In the end he was worn down and capitulated to their desires by signing the Supplemental Agreement.

Phase 3: It must have been a pleasant surprise for Professor Weinbach to see this Phase begin. It was a cordial and positive period in their relations. Both he and K&E together contributed significantly to a successful introduction of the Log Log Duplex Vector K&E 4083 Slide Rule. It probably gave him real satisfaction to see the sales of the new slide rule increase every year starting from the beginning of its introduction in 1939.

Phase 4: This Phase must have arrived as a most unexpected shock to the Professor. It is the Author's opinion that K&E and their counsel grossly overreacted to his report of the meeting he had with the two gentlemen. K&E's counsel was mistaken to recommend suspension of Royalty payments. They must have realized other companies would have interest from time to time and would naturally approach Professor Weinbach. Also, they knew that there was not a lot of time left on the Supplementary Agreement. It was to expire on December 31, 1947 when Royalties would end anyway. In reaction to K&E's letter Weinbach felt there was no recourse but to sue them for breach of contract.

K&E chose well as their attorneys were able, by numerous legal maneuvers over a sixteen month period, to hold off any decision by the court. With costs rising and time running longer than anticipated Weinbach was more than likely forced to a settlement.

Sadly, if the share of the Settlement to Weinbach was around \$10,000 it seems in no way satisfactory when one considers his long time contributions to K&E's fortunes. After all of his efforts Weinbach must have been very tired. He was in ill health, and his wife, Regina, had passed away only a few months before in February 1945, which added to his burdens. If the case did end in such a small settlement it must have been very hard for him to swallow. Then, less than a year later, on March 29, 1947, he was dead.

As for K&E, thanks to Weinbach they had enjoyed a virtual monopoly during those many years. From 1930 – 1948 there were no other slide rules on the market that could provide solutions of complex hyperbolic functions as directly and easily. K&E just never seemed to appreciate what Professor Weinbach had accomplished.

However, others understood its importance. Remember back in 1928, when Professor A. E. Kennelly, of Harvard University, said this about the rule, "I think it should give valuable service to electrical engineers employing complex numbers and complex angles as many of us do now. I congratulate you on achieving this possibility." Also, Professor Weinbach's colleagues throughout the academic world and in industry recognized the

value of his contributions by frequent remarks and letters of praise to him - and by purchasing almost 24,000 slide rules based upon his original design.

Well Readers, the Author hopes you have enjoyed this long look at events starting so many years ago. We are fortunate that these papers were preserved for all of these years by members of Professor Weinbach's caring family, and by his Grandson, Richard Kershenbaum. Later, when received at the University of Missouri-Columbia, they were professionally assembled by a dedicated Archives staff. It is very rare to find documents existing such as these that give an entire picture for us. I have tried to make the presentation of this important historical record as complete as possible. My purpose for this Article was to give you a rare and unique look at the development of these slide rules – and at the same time give life to Professor Weinbach and the others involved. It is my hope you will agree that this goal has been reached.

Acknowledgements:

I would like to thank the following who gave so much time and helped me so well during my visit in May 2007 to the University of Missouri-Columbia campus, and also later during the preparation of this Article:

Michael E. Holland, C.A. University Archivist.

Gary D. Cox, C.A. Reference and Public Services Archivist.

Susan Wampler, Director of External Relations, Engineering Development Office.

Michael J. Devaney, Ph.D., P.E., Professor and Associate Chair, Electrical and Computer Engineering.

Assisting me with continuous support through the entire period of work on this Article were;

Richard Kershenbaum, grandson of Professor Weinbach.

Kathryn Hurley, my daughter, and Steve Hurley, her husband.

Also, I thank all of the above, Ted Hume, Clark McCoy, and Richard Smith-Hughes for reading the Drafts of this Article and offering suggestions for improvement. Needless to say, any omissions and errors are mine alone.

Bibliography:

1. Weinbach, M. P., "Vector Calculating Devices", *The Proceedings of the Regional Meeting of the American Institute of Electrical Engineering*, St Louis, March 7-9, 1928.
2. Puchstein, Albert F., "Device for Making Vector Calculations", *U. S. Patent No. 1,487,085*, Issued May 25, 1924.
3. Kennelly, A. E., *Tables of Complex Hyperbolic and Circular Functions*, Harvard University Press, Cambridge, Mass., 2nd Edition, 1921.
4. Grover, C. A., *Hyperbolic Functions, Their Derivation and Applications in Vector Algebra*, Classifax Publications, Manchester, U. K., 1948.
5. Hodgman, C. D. and Lange, N. A., *Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., Cleveland, Ohio, 1929
6. Vega, Baron Von, *Logarithmic Tables of Numbers and Trigonometrical Functions*, D. Van Nostrand Company, New York, N. Y., 1856
7. Becker, G. F. and Van Orstrand, C. E., *Hyperbolic Functions (Smithsonian Mathematical Tables)*, Washington, D. C., 1909

8. Weinbach, M. P. and Puchstein, A. F., *The Log Log Vector Slide Rule instruction manual*, New York: Keuffel & Esser Co., 1930. (For the K&E 4093 slide rule).
9. Weinbach, M. P., *The Log Log Duplex Vector Slide Rule instruction manual*, New York, Keuffel & Esser Co., 1939. (For the K&E 4083 slide rule).
10. McCoy, Clark, web site of K&E Catalogs: www.mccoys-kecatalogs.com
11. Hughes, Richard Smith, "On the Evolution of K&E Vector Slide Rules", *The Journal of the Oughtred Society*, Vol. 14, No.1, 2005.
12. Robinson, W. K., "Listing of All known Slide Rules with Hyperbolic Scales", *The Journal of the Oughtred Society*, Vol. 14, No.1, 2005, in the JOS Plus Section.

Appendix 1: The Weinbach Slide Rule and Hyperbolic Functions of Complex Numbers

This Appendix will show the significant impact that Weinbach's slide rule had on problems involving complex hyperbolic functions. With his rule, values of complex expressions such as $\sinh(u + j\theta) = A e^{j\theta} = A/\underline{\alpha}$, in the Vector form; or, $\sinh(u + j\theta) = (x + jy)$, in the Cartesian form could now be quickly obtained. Compared with the then current hand calculation routine this breakthrough was a most valuable and timesaving tool as we will see in the following discussion. But first, without getting too deep in the mathematics, we will give a short explanation of what Weinbach was facing in designing a slide rule to solve these problems.

A typical complex hyperbolic number problem would involve either the calculation of $A/\underline{\alpha}$ in the Vector form, or, the calculation of the values of x and y in the Cartesian form. For example, the formulas for solving $\sinh(u + j\theta) = A/\underline{\alpha}$, in the Vector notation, are;

$$A = \sqrt{(\sinh^2 u + \sin^2 \theta)}, \text{ or } A = (\sinh u \cdot \cos \theta / \cos \alpha); \text{ and} \\ \alpha = \tan^{-1}(\cosh u \cdot \sin \theta / \sinh u \cdot \cos \theta); \text{ or } \alpha = \tan^{-1}(\tan \theta / \tanh u).$$

If instead one wished to solve for the Cartesian values of x and y the following formulas would be used:

$$\sinh(u + j\theta) = (x + jy) = [(\sinh u \cdot \cos \theta) + j(\cosh u \cdot \sin \theta)].$$

In this equation, $x = (\sinh u \cdot \cos \theta)$, and $y = (\cosh u \cdot \sin \theta)$.

We see from these that the solution of a hyperbolic function of a complex number is also a complex number.

Similar looking Vector and Cartesian formulas exist for solving the other complex hyperbolic functions, i.e., $\cosh(u + j\theta)$, $\tanh(u + j\theta)$, and the reciprocal functions $\operatorname{cosech}(u + j\theta)$, $\operatorname{sech}(u + j\theta)$, and $\operatorname{coth}(u + j\theta)$.

Now the challenge Weinbach had was to design a slide rule that would handle all of these various and complicated calculations – including those for all six of the complex hyperbolic functions. Notice that the solution shown for each equation above involves one, or more, of the trigonometric functions combined with hyperbolic functions - and, might include other operations as well. This means there must always be trigonometric scales working along with the hyperbolic scales on the slide rule in order to solve these complex hyperbolic expressions. Weinbach was able to design his slide rule so that these different sets of scales would provide the needed solutions. This was a significant achievement. (Author's insert: I make the comment more than once in the Article that K&E did not seem to understand Weinbach's arguments about the trigonometric scales, and the need for these to be decimally divided in order to work with the hyperbolic scales. K&E claimed that the hyperbolic scales were separate from the others. This was wrong. It is the Author's opinion, that K&E was not that mathematically literate at this higher level of complex hyperbolic problems. And for that reason, never did understand the absolute necessity for the two sets of scales, trigonometric and hyperbolic, to mesh in harmony for the slide rule to function properly. Weinbach did, but unfortunately K&E just did not see, or did not want to see, what he was trying to explain to them).

In the days before Weinbach's slide rule these formulas involved formidable calculations. To solve these equations one had to consult published mathematical tables. Then look up the hyperbolic functions in one set of tables and the circular functions in another. (Remember, the hyperbolic functions were looked in the tables in radians, but

the circular functions had to be in degrees before table look up. One or the other had to be converted to degrees or radians before using the tables). Complicating the calculations was the fact that these look ups were almost always required to be in log tables – and often interpolations within the tables were encountered that added to the difficulty of the work. Log tables were used for these calculations because of the multiplication and division operations in the formulas. Anyone who has worked with logs and anti-logs knows they often are confusing to use. Calculations are time consuming and one has to be very careful not to make mistakes. However, there was little alternative at the time, for without log tables to use the calculations would have had to be done by hand using long multiplication and long division.

After 1914 the work may, or may not, have been simplified if one had a copy of the “Tables of Complex Hyperbolic and Circular Functions”, by Kennelly. Using his tables one could obtain approximations to the values - and more importantly a means to check the results obtained by the long hand calculation process. In his 1928 article Weinbach said, “The ‘Kennelly Tables’ give the vector values and the equivalent complex numbers of the above mentioned functions for values of u in steps of 0.05 and values of θ in steps of 4.5 deg. Double interpolations are necessary, however, if the values of u and θ differ from those given in the table”. This probably meant that most of the time the calculations involved double interpolations. These were not easy to do.

As we will see, Weinbach’s introduction of his slide rule with hyperbolic scales presented a powerful tool for both making and checking these complex calculations, and in much less time. To show the power of his slide rule we will first show a calculation of $\sinh(u + j\theta) = A/\alpha$ by the hand calculation method. Then slide rule examples will be shown using the K&E 4093 and 4083 rules. This will allow us to compare the solution by the hand calculation method with the solutions by slide rule.

There is little doubt, as we will see, that the introduction by K&E in 1930 of the slide rule with hyperbolic scales was an important breakthrough in slide rule history. For eighteen years, from 1930 to 1948, K&E had a monopoly as no other manufacturer had a similar slide rule in the market with hyperbolic scales. During that time these two slide rules became the leading tool for engineers and scientists to solve and check calculations involving both hyperbolic and complex hyperbolic functions. It should be mentioned that Hemmi from the early 1930’s had two hyperbolic rules. Model No. 153 of Gudermannian design, and the 20 inch Model No. 154. However, they really were not competitive with the K&E rules as one could not directly or easily solve the many problems involving complex hyperbolic functions with them. After World War II Hemmi introduced their Model No. 255 Duplex Slide Rule. With this slide rule one could solve complex hyperbolic functions directly. This was the first slide rule that could match the operations of the K&E 4083. However, it and the other Hemmi rules only appeared in the U.S. market in very limited numbers so they were never a challenge to K&E’s market dominance. In fact, it was not until 1948 that Pickett & Eckel, and Dietzgen began to introduce their models with hyperbolic scales in sufficient numbers to compete with the K&E 4083 slide rule. (Author’s insert: Of interest is that the Pickett Model 4 had the hyperbolic scales on the slide similar to Weinbach’s original design in his 1928 paper. The Dietzgen No. 1735 looked so like the K&E 4083 that many mistakenly thought K&E had manufactured it).

For making our comparisons we will start with an example using the hand calculation method, and then move on to the calculations by slide rule. In our examples we will solve $\sinh(u + j\theta) = A/\alpha$, using sample values for u and θ , and these formulas:

$$\alpha = \tan^{-1}(\tan \theta / \tanh u); \text{ and, } A = (\sinh u \cdot \cos \theta / \cos \alpha).$$

We will pretend that the time period in which we are doing the hand calculation is pre-1930, before the introduction of Weinbach's slide rule. Our calculation will be done using published log tables that were usually on every engineer's desk at that time. At least on the desks of those doing these types of calculations on a regular basis. For our example we will use the following tables to look up the values by hand: For the regular trigonometric (circular) functions we will use the *Handbook of Chemistry and Physics*, 1929; for the logs of the trigonometric functions we will use *Logarithmic Tables of Numbers and Trigonometrical Functions*, by Vega, 1856; and, for the logs of the hyperbolic functions we will use *Hyperbolic Functions (Smithsonian Mathematical Tables)*, by Becker and Van Orstrand, 1909).

Following is our example, showing the look up sources used, and the steps involved in the calculation of $\sinh(u + j\theta) = A/\alpha$, where $u = 0.243$ and $\theta = 53^\circ 30'$:

<u>For $\alpha =$</u>	<u>$\tan^{-1}(\tan \theta / \tanh u)$</u>	<u>Look up Source</u>	<u>Log Value</u>	
Step 1.	$\log \tan \theta =$	Vega p 509	0.1307911	
Step 2.	$\log \tanh u =$	B & VO p 24	9.3771700	-10
Step 3.	$\log \tan \theta = \pm 10$	Step 1 ± 10	10.1307911	-10
Step 4.	$\log \tan \theta - \log \tanh u =$	Step 3 – Step 2	0.7536211	0
Step 5.	$\text{anti-log}(\tan \theta / \tanh u) =$	Vega p 99	5.67045	
Step 6a.	$\alpha = \tan^{-1}(\text{Step 5})$	HB of C&P- P103	79° 59.9'	
Step 6b.	$\alpha =$ (from Step 6a. to decimal °)		79.99833	°
<u>For A =</u>	<u>$(\sinh u \cdot \cos \theta) / \cos \alpha$</u>			
Step 7.	$\log \sinh u =$	B & VO p 24	9.3898700	-10
Step 8.	$\log \cos \theta =$	Vega p 509	9.7743876	-10
Step 9.	$\log \sinh u + \log \cos \theta =$	Step 7 + Step 8	19.1642576	-20
Step 10.	$- 10$	Step 9 - 10	9.1642576	-10
Step 11.	$\log \cos \alpha =$ (α is from Step 6)	Vega p 350	9.2397000	-10
Step 12.	$\log A = \log \sinh u + \log \cos \theta - \log \cos \alpha =$	Steps 10 – 11	-0.0754424	0
Step 13.	$\log A = \pm 10$ (from Step 12)		9.9245576	-10
Step 14.	$A =$ (anti-log of $\log A$ from Step 13)	Vega p 154	0.84054	

So, the solution of $\sinh(u + j\theta) = A/\alpha$ is; $\sinh(0.243 + j 53^\circ 30') = 0.84054 / 79.99833^\circ$

If you actually do these steps by looking up the values in the tables you will very quickly see that this hand calculation method is not simple or easy. It is really quite laborious. Remember that back then all calculations were recorded by hand using pencil and paper. Starting with the books of tables in front of me, and a pencil and pad of paper, it took 27 minutes for me to complete this hand calculation – and recheck the work. I would be interested to hear from readers as to how long it took them to complete this same example using published tables.

Slide Rule Example No. 1 using the Log Log Vector, K&E 4093:

Below is the example using the K&E 4093-3 slide rule to solve $\sinh (0.243 + j 53^\circ 30')$ for A / α . First we will convert $53^\circ 30'$ to decimal degrees of 53.5° . (Note: to save space we will use the symbol \downarrow to denote the use of the hairline on the cursor).

For the direct solution of α the steps are :

- (1). With the scales aligned set \downarrow to 53.5° on scale TI black;
- (2). Move right index on scale SII to 0.243 on the Th scale;
- (3). Under \downarrow on scale TI black read 80° . So, $\alpha = 80^\circ$.

For the direct solution of A the steps are :

- (4). With the scales aligned set \downarrow to 0.243 on ShI ;
- (5). Move slide so that 53.5° on scale $SI2$ black is under the \downarrow ;
- (6). Move \downarrow to 80° on scale $SI2$;
- (7). Read value of 0.84 under \downarrow on scale D ; So, $A = 0.84$

And, the solution by the K&E 4093 slide rule is:

$$\sinh (0.243 + j 53.5^\circ) = 0.84 / 80^\circ$$

Starting with the Log Log Vector instruction manual to guide me, and a pencil and pad of paper, it took 4 1/2 minutes for me to complete this slide rule calculation.

Slide Rule Example No. 2 using the K&E 4083:

We will now show the solution for this example using the K&E 4083 slide rule introduced in 1939 to solve $\sinh (0.243 + j 53^\circ 30')$ for A / α .

For the direct solution of α the steps are :

- (1). set \downarrow to right index on D and move 53.5° on T (red) under the \downarrow ;
- (2). move \downarrow to 0.243 on Th , and under \downarrow read 80.0° on scale T (red); So, $\alpha = 80^\circ$

For the direct solution of A the steps are :

- (3). set \downarrow to 0.243 on ShI ;
- (4). set 80.0° on scale S (red) under the \downarrow ;
- (5). move \downarrow to 53.5° on scale S (red);
- (6). read value of 0.84 under \downarrow on D . So, $A = 0.84$

And, the solution by the K&E 4083-3 slide rule is:

$$\sinh (0.243 + j 53.5^\circ) = 0.84 / 80^\circ$$

It took 3 minutes for me to complete this slide rule calculation. Notice how much easier and faster the steps have become using the K&E 4083 slide rule vs. those used for the K&E 4093.

We solved for the complex Vector form A / α when doing the above examples. This form is more often preferred as it is particularly useful for multiplying and dividing these complex hyperbolic numbers. As another example we will now show a solution of x and y using the Cartesian form. Here we will solve $\sinh (0.243 + j 53.5^\circ) = (x + j \cdot y)$. The formulas for solving for x and y are:

$$x = (\sinh u \cdot \cos \theta); \quad y = (\cosh u \cdot \sin \theta);$$

We will not show the detail listing of calculations using logarithms here to save space. However, the solution of these equations for x and y by the long hand method using logarithms is: $x = 0.14597$ and $y = 0.82771$. Looking up the logs in the published tables took me 18 minutes to solve for these by hand using pencil and paper.

Using the K&E 4083-3 slide rule we will proceed as follows:

For the direct solution of x the steps are :

- (1). set \uparrow to 0.243 on *ShI*;
- (2). set right index on *S* to \uparrow ;
- (3). move \uparrow to 53.5° on scale *S (red)*;
- (4). read $x = \mathbf{0.146}$ under \uparrow on *D*

For the direct solution of y the steps are :

- (5). set left index of *C* to 0.243 on *Th*;
- (6). move \uparrow to 0.243 on *ShI*;
- (7). turn rule over read 1.03 on *C* scale under \uparrow ;
- (8). turn rule back over and set left index of *S* to 1.03 on *D*;
- (9). move \uparrow to 53.5 on *S black*;
- (10). read $y = \mathbf{0.828}$ under \uparrow on *D*

And so, $\sinh(0.243 + j 53.5^\circ) = (0.146 + j \cdot 0.828)$

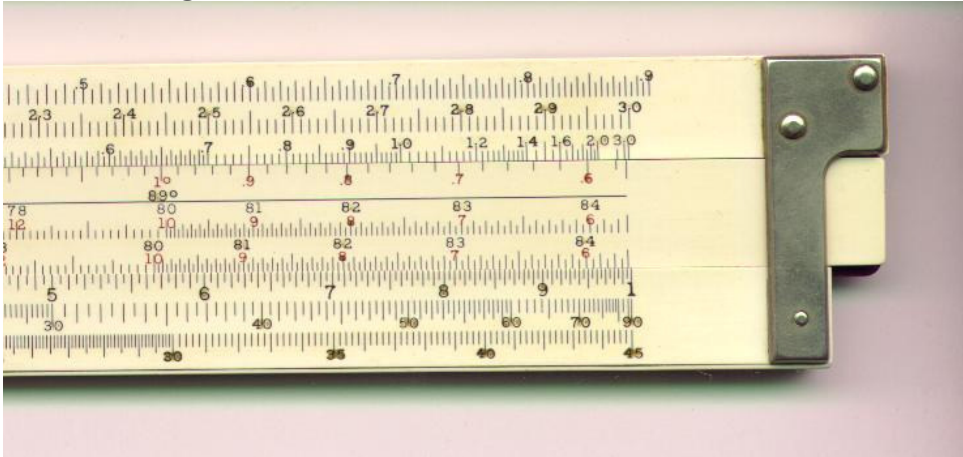
These slide rule calculations took 3.5 minutes for me to complete.

It is very obvious from these examples that using the K&E slide rules with hyperbolic scales is much easier and faster than trying to calculate $\sinh(u + j\theta) = A / \alpha$, or $(x + jy)$, by hand calculations using values from published tables. Of real importance is the fact that it does not take very many sample calculations with the slide rule to find that one masters these steps quite readily. One can imagine how happy those working with hyperbolic complex functions were to see the K&E 4093 and 4083 rules. These freed them from many time consuming log table look up routines.

There was another advantage. The table look up routines would have been used, instead of the slide rule, when more accuracy (more decimal places) was desired than could be obtained by using the slide rule. However, after completing the long hand calculations made from using the published tables the slide rule could be used to quickly check the answers. In this way the slide rule proved to be a valuable checking tool to have, for often one would find that the lengthy log calculations done by hand were prone to error.

Appendix 2: Pictures of the K&E 4093 Slide Rule (Continued)

Back Side Right



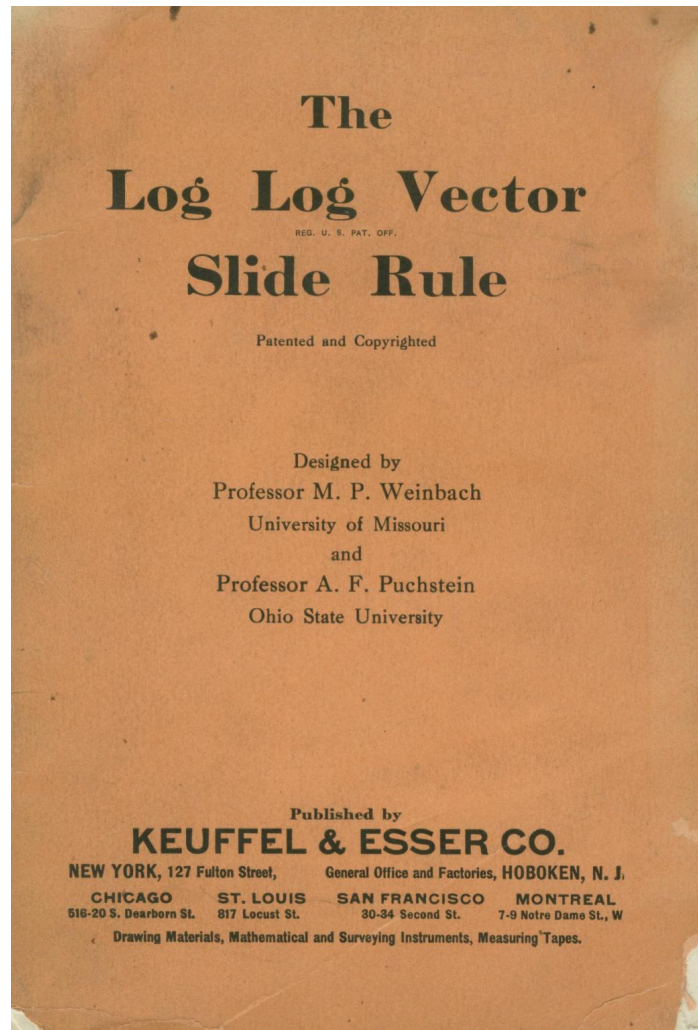
The 4093-3 was introduced in late 1929, and first shown in the K&E's 1930 catalog. It last appeared in the 1938 catalog price list. The locations of the scales on the 4093-3 and the 4093-5 remained the same in all years. Following are the catalog listings:

- 1930 - The 4093-3 was released and the only model shown.
- 1931 - The 20 inch 4093-5 was added to the catalog.
- 1936 - The Improved metal rimmed cursor was introduced for both models. The logo showing references to the Patent numbers was changed to three numbers.
- 1938 - The 4093-3 and 4093-5 last appeared in the 1938 price list.

Consult Clark McCoy's web site of K&E Catalogs for more details.

Notice the Patent date of March 25, 1924 on the Front Side Right. This is the date of Puchstein's Patent. Why K&E included this date on the rule is odd as Puchstein's Patent had nothing to do with the arrangement of the scales on the K&E 4093. In fact, we know the layout of the scales on the K&E 4093 was copied from Weinbach's original design, and not Puchstein's.

Appendix 3: The Cover of the K&E 4093 Slide Rule Manual



It is too small to read, but under the second “Log” in the name “The Log Log Vector Slide Rule” is the word “Trademark”. Also, the cover shows the rule is both “Patented and Copyrighted”. This wording is confusing as there is no evidence that this actual slide rule, the K&E 4093, was ever Patented or Copyrighted by K&E. It does not seem to make sense, but maybe they were indirectly referring to Puchstein’s 1924 Patent, and Weinbach’s 1928 Copyright. Their names are both shown under the heading “Designed By”. One wonders what Professor Weinbach might have thought when he saw the manual cover for the first time. He did almost all of the work, and thanks to K&E, Puchstein gets half of the credit.

At the bottom of the first page the Manual shows, “Copyright 1930, by KEUFFEL & ESSER CO”. Then on a later version of the cover the word “Trademark” was replaced by the words “Reg. U. S. Pat. Off.”. Below the words “Slide Rule” the number “No. 4093” was added. Also, a new office in Detroit was listed at the bottom along with the other offices.

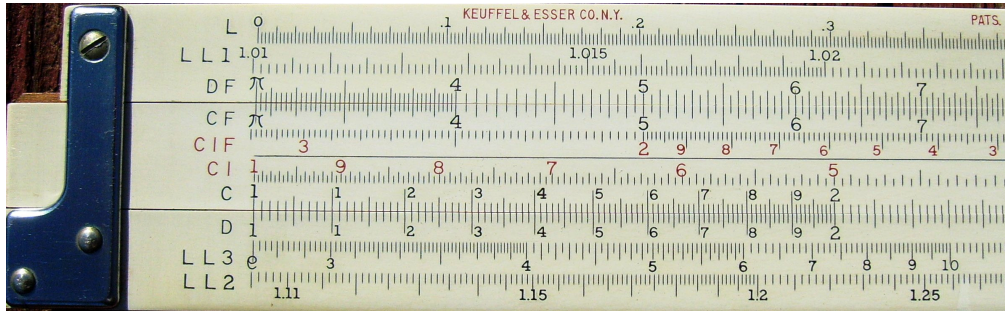
Appendix 4: The 20 inch K&E 4093 Slide Rule



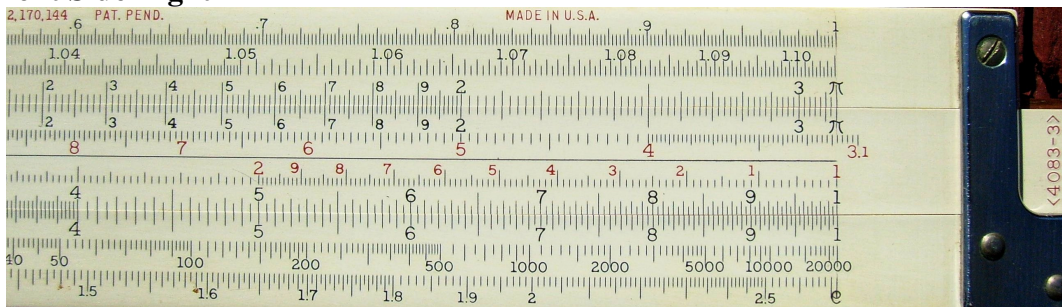
Printed in large black India ink letters on the big slide rule case are the words, “M. P. WEINBACH JANUARY 25, 1931”. This date is the day that the Professor received the 20 inch rule in the mail from K&E, and he obviously was proud of it. The smaller slide rule that was found in his artifacts and displayed in the frame is a K&E 4041 model. This Mannheim type rule was first issued by K&E around 1900. We can only surmise that Weinbach, when a student, could have purchased this as his first slide rule in the early 1900’s, and then used it for many years.

Appendix 5: Pictures of the K&E 4083 Slide Rule

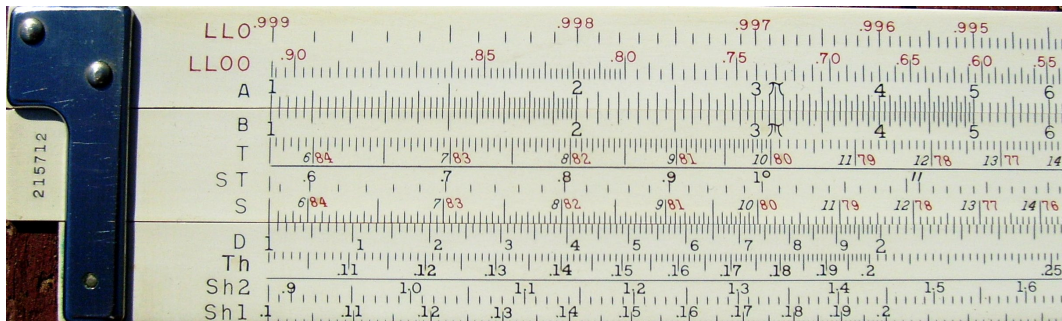
Front Side Left



Front Side Right

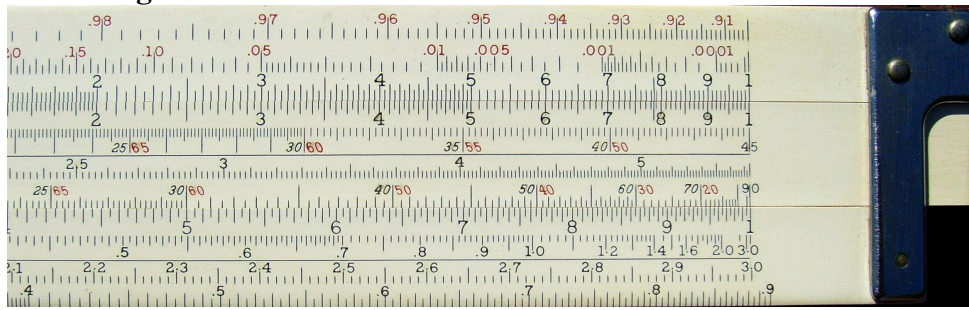


Back Side Left



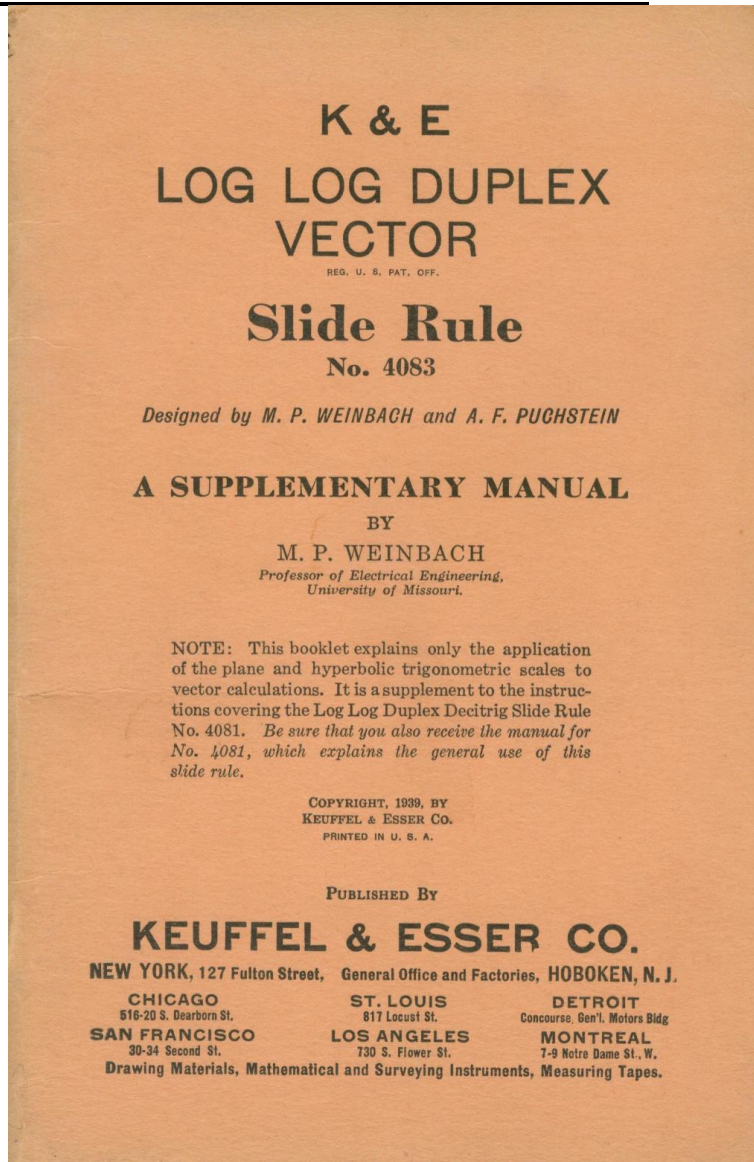
Appendix 5: Pictures of the K&E 4083 Slide Rule (Continued)

Back Side Right



The K&E 4083 was a better designed slide rule than its predecessor, the K&E 4093. However, it did have the same minor design flaw the K&E 4093 had. This was that it did not have C and CI scales on the slide on the back hyperbolic side. So, to get the answer for some calculations you had to turn the slide rule over in order to read the result under the opposite side hairline. This drawback was easily solved for both rules before starting work with hyperbolic functions. You would just pull the slide out, flip it over, and reinsert it. This trick greatly improved the operation and accuracy of the rule. You would not do this when working with hyperbolic complex functions. For these the slide needed to remain in its usual place. This was because the trigonometric and hyperbolic scales had to be on the same side so they could work together. This was only a small inconvenience, and was not important when one considered the much improved design of the K&E 4083.

Appendix 6: The Cover of the K&E 4083 Slide Rule Manual:



This cover is similar to that of the K&E No. 4093 with a few variations. Below the word “Vector” are the words “Reg. U. S. Pat. Off.”. Then below the words “Slide Rule” the number “No. 4083” was added. It does give proper credit to its author as it shows this Supplementary Manual was written by M. P. Weinbach. However, for some strange reason Weinbach and Puchstein names are still listed under the heading “Designed By”. This is odd as K&E designed the No. 4083 scale layout, and then Weinbach completed the Manual. Puchstein was not involved in either phase.

A number of changes were made in the K&E 4083 over the years and these are shown in Appendix 8. Sometime after the original Manual printing Weinbach’s name was omitted as author of the Manual. This may have occurred before 1947 as I have a copy for the year that is identical to the original Manual that does not have Weinbach’s name on the cover. It seems K&E did not like it when the Professor sued them in 1945, and dropped his name from the Manual.

Appendix 7 - M. P. Weinbach Royalty Reports - Years 1929-1943

The Royalty amounts are actual as shown in the annual reports in the Archive files; except for year 1932 that was missing and is estimated. The effect on sales caused by the Great Depression is obvious in the early 1930's. K&E did not report the number of slide rules sold each year so this is estimated. The numbers are conservative as it was assumed all sales were made with rules having the more expensive leather cases. The Royalties and Numbers sold in the two Tables by Type and Size are estimated.

<u>Sales Year</u>	<u>Report Date</u>	<u>Royalty Amount \$</u>	<u>Est.No. Sold</u>
1929	2/19/1930	73.60	109
1930	2/02/1931	405.04	660
1931	2/11/1932	348.96	569
1932	2/01/1933	224.00	365
1933	2/02/1934	144.76	236
1934	1/20/1935	500.00	815
1935	2/01/1936	582.72	950
1936	2/04/1937	689.28	1,288
1937	2/01/1938	847.96	1,453
1938	2/01/1939	759.96	1,303
1939	2/01/1940	1,421.46	2,458
1940	2/01/1941	1,472.32	2,546
1941	3/02/1942	1,927.80	3,215
1942	2/23/1943	1,775.96	2,962
1943	3/01/1944	<u>2,914.38</u>	<u>4,860</u>
	TOTAL	14,088.20	23,791

Estimated Royalties and Number by Type of Rule

<u>Type of Rule</u>	<u>Royalty Amount \$</u>	<u>Est.No. Sold</u>
K&E 4093	4,576.28	7,749
K&E 4083	<u>9,511.92</u>	<u>16,042</u>
TOTAL	14,088.20	23,791

Estimated Royalties and Number Sold by Size of Rule

<u>Type of Rule</u>	<u>Royalty Amount \$</u>	<u>Est.No. Sold</u>
10 inch	13,286.45	23,196
20 inch	<u>801.75</u>	<u>595</u>
TOTAL	14,088.20	23,791

K&E suspended Royalty payments after 1943. With returning World War II veterans the 1944-1947 nationwide University enrollment exploded. As a result of the expanded sales during those four years Weinbach lost a substantial amount of Royalty income; and then the Supplementary Agreement ended in 1947.

Appendix 8 - Brief Listing of Changes Made to the K&E 4083-3 and 4083-5

The numbers on the K&E 4083-3 and 4083-5 slide rules, and the scales, changed over the years. After introduction in 1939 the first of these occurred nine years later in the 1948 catalog. The picture of the slide rule, the Preface page, and the cover color of the Manual were usually replaced when these changes were made. However, it appears the pages in the Manual covering Weinbach's original index and operating instructions were not changed over the years. The cover of the original manual was salmon in color. Sometime after 1945, K&E, upset at Weinbach for suing them, removed his name from the cover. A brief listing of the changes to the slide rules follows. For more details regarding these consult Clark McCoy's web site of K&E Catalogs.

1. 1948: Numbers were changed to N4083-3 and N4083-5. There were changes in the scales. A number of the Log Log scales were switched around front and back. The LL01, LL02, and LL03 scales were added in place of the LL0 and LL00 scales. Model numbers that previously were shown on the right side of the slide were moved to the top edge. Sometime in 1952-1953 inland laminate edges were added to the top and bottom edges. The manual covers were changed to Grey and Red and later to Pink and Maroon.
2. 1954: Numbers were changed back to 4083-3 and 4083-5. There were changes in the scales. Hyperbolic scales moved from bottom to top side of rule. The DI scale was added to back side, and L scale dropped. K&E printed a separate eight page DI supplement. The original Manual pages remained the same. The manual cover color was changed to green.
3. 1955: There were changes in the scales, but no change in numbers. The SRT scale was added and ST scale was dropped. K&E printed a separate six page SRT supplement. The original Manual pages remained the same. The manual cover color remained green.
4. 1962: A new numbering system was introduced. Numbers changed to 68 1424 and to 68 1429. These new numbers only denoted the kind of case ordered. The 68 1424 case was *sewed leather, chamois lined*; the 68 1429 was *synthetic leather*. No changes in the scales. The original Manual pages remained the same. The manual cover color remained green, with the numbers changed.

It appears all of these same changes as above were made to the 20 inch K&E 4083-5. However, sometime between 1962 and 1967 K&E dropped the listing for the 4083-5 from their catalog. We do not know in what year this was done as the 1963-1966 K&E catalogs are not shown on Clark McCoy's web site. However, it was no longer listed for sale in the 1967 price list. They had probably stopped manufacturing the 20 inch rules prior to 1967 and were then selling from their existing inventory. In 1972 the 4083-3 did not appear in the catalog. This was the end of the K&E "Vector" slide rule era.

THE END

XX