Title: # The Spirule (1948-1985)

Subtitle: **An Analog Computing Tool for the Root-Locus Method**

Author: **Gregory W. Evans**

Engineering History Series: The Development of the Root-Locus Method

From research behind *Into Stability: Walter R. Evans and the Story of Root Locus*

Abstract:

The Spirule was a simple mechanical device developed to assist engineers in constructing root-locus plots quickly and accurately. Conceived during the early adoption of Walter R. Evans's root-locus method, the tool combined a circular protractor with a logarithmic spiral to allow simultaneous addition of phase angles and multiplication of vector magnitudes. This paper recounts the origin of the Spirule in the engineering culture of North American Aviation in the late 1940s and its subsequent production and distribution through a small mail-order enterprise operated by Evans and his wife. Although later superseded by digital computation, the Spirule played an important role in teaching and applying graphical control-system design methods during the formative decades of modern control engineering.

Keywords:

- Spirule
- Analog Computing Device
- Root-Locus Construction
- Graphical Control Design
- Engineering Instruments
- Logarithmic Spiral
- Analog Engineering Tools
- History of Engineering Computation

The Spirule (1948-1985)

An Analog Computing Tool for the Root-Locus Method

Joined at the hip with the birth of the root locus method was the need for a tool to help designers sum angles and multiply distances from a trial point "p" on the s-plane to other fixed points. Walt's 1948 classroom notes captured his early attempt to meet that need. "Place a transparent sheet on top of the diagram, draw the red line for reference, stick a thumbtack through at the guess point to serve as a pivot."

Engineers rejected his makeshift solution. They wanted something better—something precise, durable, and repeatable. Yet few at the time, including Walt himself, could have anticipated how dramatically this problem would shape the next stage of his career. The tool's journey from plexiglass prototype to globally distributed teaching aid was a story no less remarkable than the method it served.

Jeff Schmidt was one of Walt's colleagues. His assignment in the summer of 1948 was to design an analog autopilot for the NATIV missile. It had to work without adjustment throughout the changing mass and center of gravity during the launch phase. Schmidt was stymied until Walt presented root locus. In 2003,

Schmidt recalled:*When Walt first started discussing root-locus in his class, I saw a ray of hope. While the problem was still very difficult, I could at least get a feel for what I was trying. As more people started to use Walt's method, many ideas for automating the plot were thought of. I was looking for something better than transparent paper to add angles.*

I went over to the engineering shop and made an "angle adder" out of a circle of plexiglass with a straight arm held on with a small bolt. This worked much better than the transparent paper for determining the locus, but I still had to measure lengths and multiply them to get loop gains. Walt and I were kicking this problem around one day, and we came up with the idea of adding a logarithmic spiral to my angle adder. This worked well and became the first Spirule.

The spiral-shaped curve was key to simultaneously using the principles of a linear slide rule (i.e., multiplication by addition of logarithms) and performing the addition with the circular protractor. DeWitt Lyon, a colleague of Schmidt and Walt, looked at the spiral curve on Schmidt's device and coined "Spirule" as a contraction of "spiral" and "slide rule."

In the spring of 1949, Moore invited Schmidt to lecture his graduate servo course at UCLA on the use of his Spirule. Schmidt recalled in 2003:

After the first Spirule had shown its worth, a design was made for a more precise model. A bunch were made for use in the department. After my demonstration in John Moore's servo class, employees of several large aerospace companies asked for a set of drawings. Hughes had several hundred made, but the person doing the assembly looked at the assembly drawing and cemented the parts together.. Since nothing could rotate, they were worthless..

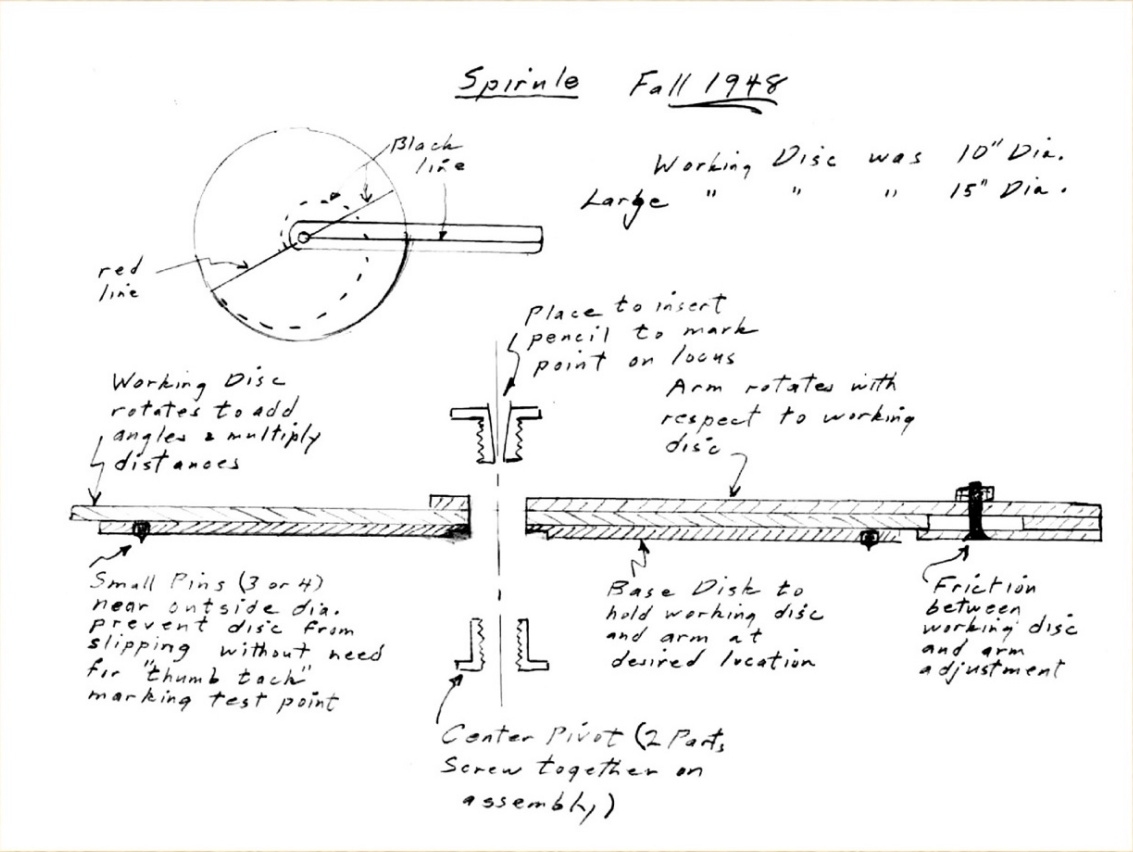
A milestone in the history of the Spirule occurred in January 1950 when Walt's root locus ideas gained their first national platform at the January 1950 winter meeting of AIEE's Feedback-Control Systems Group. Walt traveled to New York to present his paper. Surprisingly, the paper's only mention of the Spirule is as a do-it-yourself project: "The reader can duplicate the 'spirule' with two pieces of transparent paper, one for the disk and one for the arm." Hence, many in the audience would have never seen a real Spirule.

During his talk, Walt introduced the Spirule. Afterward, approximately 70 attendees expressed interest in obtaining one. Walt encouraged listeners to duplicate the Spirule for themselves with pieces of transparent paper and some additional words of explanation beyond those in the published paper. This was one of many occasions on which he suggested to others that they need not purchase a Spirule from him to teach or learn the principles involved in root locus—they could create their own. To Walt's surprise, engineers wanted Spirules.

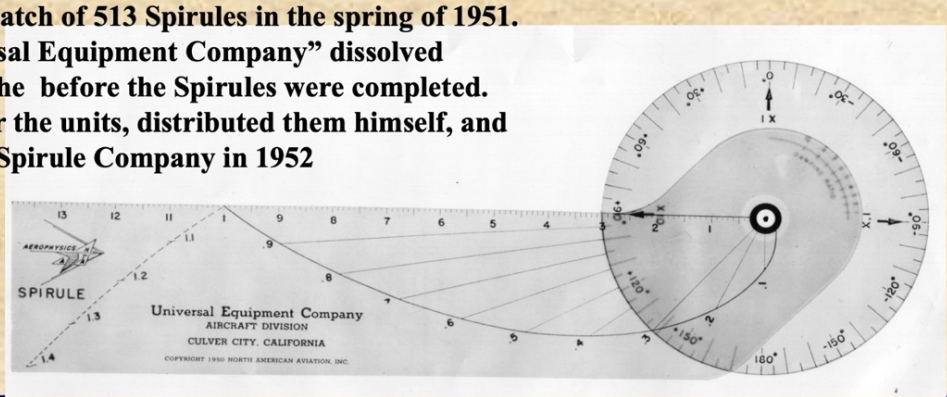
Walt returned to California expecting dozens of follow up calls. He received exactly three, all in March. The first, dated March 1, came from W. C. Osterbrock, head of the University of Cincinnati's Electrical Engineering Department. On March 21, Professor R.C.H. Wheeler from the U.S. Naval Postgraduate School asked*, "Have you made the Spirule for sale? If so, how can I obtain one?"*

Jeff Schmidt's 2003 Drawing of his 1948 Spirule

Jeff Schmidt, a Aerophysics Lab colleague of Walter Evans, was the first to have the idea of using a plastic circular protractor to aid in creating root locus plots. Mr. Schmidt drew this sketch of the device he first made in 1948 below in December 2003. Aerophysics Lab engineer, DeWitt Lyon, coined the name "Spirule."



The Cellulose Products Company manufactured the first production batch of 513 Spirules in the spring of 1951. The "Universal Equipment Company" dissolved by the time the before the Spirules were completed. Walt paid for the units, distributed them himself, and founded the Spirule Company in 1952



On March 27, W. E. Meserve, Professor of Engineering at Cornell, reminded Walt that he had promised to provide more information on obtaining the slide rule device. Walt waited until April 1950 to respond, explaining that he had delayed until he could distribute copies of his AIEE paper. His response to all three correspondents included the following:

Thank you for your interest in the root-locus idea. At the AIEE meeting, approximately seventy attendees expressed interest in obtaining a Spirule. Since then, only three have written. This presents a cost issue: $30 per unit for a machine shop model or 50 cents each for a stamped model in a lot of 500. The Spirule isn't worth $30, and the demand is far short of 500!

It looks like they won't be manufactured until I find an intermediate production method or finish writing a book in which the Spirule will be enclosed.

W.C. Osterbrock replied prophetically, encouraging Walt to manufacture Spirules and make them available for sale.

I wonder whether you are justified in your doubts about the demand for the 'spirule.' We could have disposed of 65 at a reasonable price, and we shall have another class of about 80 students in servo this summer. Other schools teaching the subject would likely recommend it if properly advertised. I hope you will find a way to produce and make it available.

The earliest Spirule drawing is an undated blueprint likely created in early 1950. The "final drawing" (was dated September 5, 1950) An October 19, 1950, NAA memorandum from R. M. Osborn to W.J. Toher requested funding to produce 500 Spirules.

Osborn noted that engineers at NAA, Hughes Aircraft, and Northrop had built their own Spirules and that root locus was already part of servomechanism curricula. He estimated production costs at 35 cents per unit in a batch of 500. He also suggested distributing them as souvenirs to visitors and educational institutions. Despite the appeal, the request became mired in bureaucracy. One week later, Dr. William Bollay delivered the Wright Brothers Lecture at the Institute of Aeronautical Sciences in Washington, D.C.

Meanwhile, interest in root locus, fueled by word of mouth, kept the idea and method alive, even without Spirules. Former NAA colleague Ward Harman had

left NAA for a position at Stanford; he enthusiastically promoted root locus. Joseph Chadwick of Stanford's Electronics Research Laboratory wrote on January 8, 1951:

Ward Harman has been such a convincing salesman of your root-locus method that he's exceeded his ability to inform. Could I obtain a couple of your celluloid gadgets for summing angles, etc.?"

And yet, at the dawn of 1951, funding for Spirule fabrication remained elusive. "Our efforts to produce Spirules have been snarled in accounting procedures because the logical approach is to manufacture them in bulk and distribute them." Walt sought manufacturers, with three companies rejecting the project and three others not responding. Finally, Cellulose Products in South Gate agreed to fabricate the Spirule. NAA contracted with Universal Equipment Company in Culver City, which received the first bill for 513 Spirules on April 30, 1951. When the partnership dissolved, Walt personally paid the bill and all Spirule orders were routed directly to him.

On March 27, 1952, Walt sent a Certificate of Business form to *The Whittier News*. On April 8, 15, 22, and 29, the following notice appeared in the classifieds: "The undersigned does hereby declare that I am conducting a mail sales business at 1706 Maple Street under the fictitious name of "The Spirule Company. "Orders continued to flow in, some sent directly to Walt at his Whittier home, some to him at his NAA Downey address, and some to the Universal Equipment Company in Culver City. The most significant development in the first quarter of 1952 was the enthusiasm of two engineering professors from the University of California—Joseph Beggs of UCLA and Otto Smith at UC Berkeley.

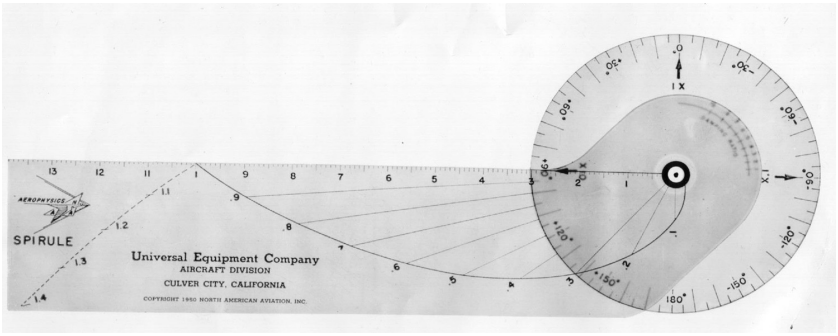
The UC schools' embrace of root locus and the Spirule into their departments' feedback control classes laid the foundation for Spirule sales to university bookstores. Joe Beggs and Otto Smith were in a vanguard of professors at UCLA, Berkeley, Stanford, and Caltech who chose to introduce the new root locus methods into their classes. Many used Brown and Campbell's 1948 *Principles of Servomechanisms* book as their text. In March, orders were received for 55 Spirules for resale by UCLA bookstore, 30 for resale by the University of California at Berkeley bookstore, and 20 for Charles Wilts's servomechanism class at Caltech.

The Spirule

A plastic device with a disk and an arm with a common pivot point. The disk and arm are held together with a light friction fit by an eyelet; a small pin is held in the center of the eyelet by a clear plastic plug.
The pin is stuck in the vector plot at the desired s point to form a pivot for all measurements at the point. Note that all phase angles and vector lengths on the plot have this s point in common.

The total phase angle is obtained by rotating the arm with respect to the disk through each of the phase angles in succession; the total angle is read on the disk at the radial edge of the arm. The spiral curve on the arm is plotted such that the angle V from the radial edge to the curve is proportional to the logarithm of the radius to that point on the curve. The arm is rotated through each of these angles in succession in order to add logarithms.

The numerical value of the product is read on the curve in line with an arrow on the disk subject to the correction xn, in which x is the numerical value on the plot corresponding to 5" and n is the excess of poles over zeros. Any such correction factor can be set into the Spirule initially and marked on the frosted surface so that all further calculations give the final value directly. Terms in F(s) of the form (1+Ts) must be treated as a ratio (1/T + s)/(1/T). The factors such as 1/T can be set in by first pivoting the Spirule at the origin and rotating the arm opposite to the usual sense.



The supply from the initial batch of 500 had begun to run dry. Even worse, the Universal Equipment Company partnership had dissolved; the new owner wanted to raise the price of the Spirule. Walt worried about the affordability of the Spirule for students.

Having successfully completed the assembly, correspondence, billing, and shipping himself for the entire manufacturing run of 500 units, Walt offered and was granted permission to assume full responsibility in the future. And so, in a modest, 1200 square foot residence in Whittier, California, the Spirule Company was born. Coincidentally, Walt and Arline celebrated their tenth wedding anniversary the same day.

Ironically, it had been exactly two years since Professors Wheeler, Osterbeck, and Meserve had learned from Walt that NAA had no plans to manufacture Spirules because they were "not worth $30 and the demand is far short of 500 [for a $0,50 stamped model.]"

On the face of it, the decision to launch a mail-order business out of their residence seemed ill-advised. In April 1952 Arline was six-months pregnant and burdened with Randy and me. Walt's and Arline's parents and siblings lived 2000 miles away. Walt had demands at work and faced hard-to-meet publication deadlines for *Control-System Dynamics.*

Why then, did he choose to assume responsibility for Spirules? In part because he underestimated demand. Of all the feedback he received from the root locus method, the universal desire of designers and students to plot root loci with Spirules rather than two transparent pieces of plastic pinned with a thumbtack to a "genius pad", was probably the least expected. He once remarked in a letter, "Engineers must love gimmicks," Jeff Schmidt deserves credit for the design. Walt "closed the loop" with a business model that met the demand.

Luckily for him, in Arline, he had married a woman with high energy and finely-tuned time-management skills, who was fully committed to his success, and content to work quietly behind the scenes. She was his executive assistant, corresponding secretary, accountant, and filing clerk in addition to being an efficient home maker, and mother to his children. When anyone complimented Walt on his children, his response was always the same: "it's not me, it's Arline."

One Sunday morning, Walt's son answered the front doorbell still in his pajamas. A bewildered engineering student stood there and asked, "Is this The Spirule Company?" He'd driven to their house—likely desperate on the eve of an exam. The Spirule was sold in bookstores, but for him, salvation lay closer to the source.

Instructors worldwide adopted the Spirule for control systems courses; it appeared in dozens of textbooks, particularly throughout the 1960s and 1970s. From universities to defense contractors, its influence was pervasive. Between 1952 and 1986, Spirule sales reached more than 101,000 users in 50 states and 76 countries.

Among the thousands of orders, several stood out. In February 1959, about one year after Walt revamped the Spirule design, he received a kind letter from Professor John G. Truxal, now head of the prestigious engineering department at the Polytechnic Institute of Brooklyn.

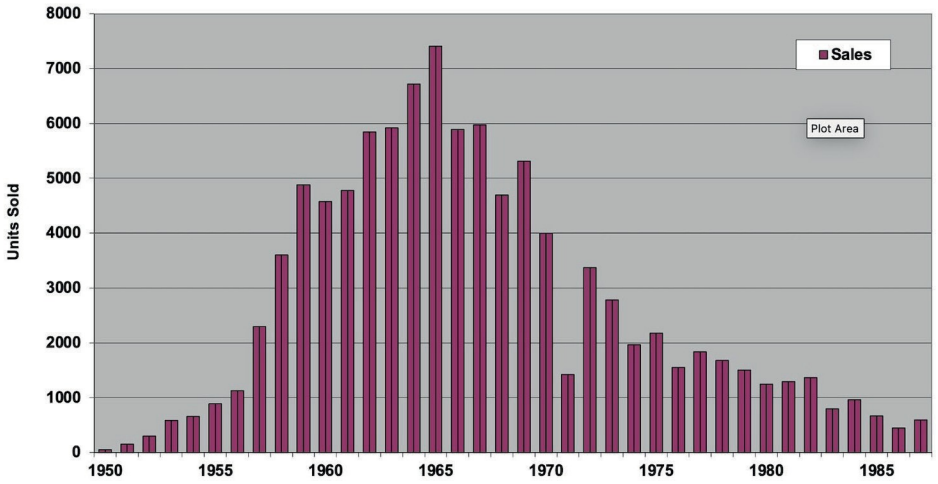
Dear Mr. Evans,
Thanks very much for sending me the new model Spirule. I am very impressed with the construction of this model and I anticipate that we will ask our students to obtain it in the fall's classes. I certainly am sold on your root locus method implemented with the Spirule and consider this the outstanding postwar contribution to the control field.

Sincerely, John G. Truxal

Noteworthy letters need not have been written by noteworthy authors. In 1973, Arline received a letter from the Philippines. Its author, Ho Hwa Hui, asked simply, "How much does a Spirule cost?" Without hesitation, Arline mailed one out the same day, trusting he'd pay. He did—and more.
His reply read:

You have unknowingly given me a two-fold surprise package. First, you sent the Spirule to a complete stranger thousands of miles away without even a guarantee that you'd get paid! Secondly, you are Mrs. W. R. Evans—wife of one of the most respected and prestigious control engineers in the forefront of this highly technical field. Of course, I don't have to tell you.

Annual Spirule Sales



Annual Spirule Sales (Top)

List of Countries where Spirules have been shipped (bottom.)

Argentina	**El Salvador**	**Kenya**	**Saudi Arabia**
Australia	**England**	**Korea**	**Scotland**
Austria	**Finland**	**Lebanon**	**Singapore**
Belgium	**France**	**Libya**	**South Africa**
Brazil	**Guatemala**	**Mexico**	**Soviet Union**
Canada	**Greece**	**Mozambique**	**Spain**
Ceylon	**Honduras**	**The Netherlands**	**Sudan**
Chile	**Hong Kong**	**New Zealand**	**Sweden**
China/Taiwan	**Iceland**	**Nigeria**	**Switzerland**
Columbia	**India**	**Norway**	**Thailand**
Costa Rica	**Indonesia**	**Oman**	**Turkey**
Cuba	**Iran**	**Pakistan**	**Uganda**
Cyprus	**Iraq**	**Panama**	**United States**
Czechoslovakia	**Ireland**	**Peru**	**Uruguay**
Denmark	**Israel**	**Philippines**	**Venezuela**
Dominican Republic	**Italy**	**Poland**	**Wales**
Ecuador	**Japan**	**Portugal**	**West Germany**
Egypt	**Jordan**	**Puerto Rico**	**Yugoslavia**

Walt priced the Spirule barely above cost, aware that most of his customers were students. Orders arrived for decades, addressed to the home he moved into in August 1954: 9728 El Venado Drive, Whittier.

The Spirule was the physical manifestation of Walt's root locus method. It was a tool that embodied the core principle of plotting how the roots of a characteristic equation move with changes in system parameters. It transformed abstract mathematics into a designer's tool—repeatable and fast.

Because of that, it outlived the era of analog computing and slide rules. The root locus method became embedded in MATLAB code and CAD tools. Its teaching value—as a graphical, hands-on, geometry-based approach—remains foundational in control theory instruction to this day. That is the legacy of The Spirule Company. And it is inseparable from the vision and values of Walter R. Evans.

About this Paper:

This paper is derived from research presented in *Into Stability: Walter R. Evans and the Story of Root Locus* (Evans, 2025) and examines the historical development of the root-locus method within the engineering culture of the early Cold War.

About the Author:

Gregory W. Evans is a graduate of the California Institute of Technology (1969) and Stanford University (1975) and served as a Distinguished Technical Fellow at TRW. He is the author of *Into Stability: Walter R. Evans and the Story of Root Locus* (Evans Heritage Press, 2025) and is the son of Walter R. Evans

More information is available at WalterREvans.com. . [greg@walterrevans.com]

On April 8, 1950, 18 months before the first Spirule sale and two years before the creation of the Spirule Company, Walt responded to three spirule inquiries.

In each of these letters, Walt remarked:

" …the following problem in costs: $30 each for a machine shop model, 50c each for a stamped model in a lot of 500. It's not worth $30 and the demand is far short of 500."

On April 8, 1952, Sheldon Saks wrote an inquiry for a Spirule that exhausted the first production run of 500.

The Spirule Company was born.

1706 Maple St.
Whittier, Cal.
April 8, 1950

Professor W. C. Osterbeck
Dept. of Electrical Engineering
University of Cincinnati
Cincinnati 21, Ohio

Dear Professor Osterbeck:

Please pardon my delay in answering your letter of March 1; I was waiting to receive the AIEE copies of the paper which had been ordered. Three copies of the paper are enclosed; I am sorry that the required condensation eliminated the details of how any one problem is completely solved. Some of the synthesis short cuts mentioned at the meeting are not included in the paper. In particular the locus can be plotted versus almost any parameter of the system , such as the value of a capacitance in a lead cirucit, rather than just loop gain. The main line of reasoning here is that the system could be described by a set of simultaneous equations with the roots being the values which make the characteristic determinant equal to zero. This determinant could be expanded in the form:

F
$F_1(s)$ C $F_2(s)$ 0

The zeroes of
The zeroes of $F_1(s)$ are the system roots for C 0 and the zeroes of $F_2(s)$ are the system roots for C These two special cases are fairly easy to solve, so that $F_1(s)$ and $F_2(s)$ are known in factored form. The locus verus C as a "loop gain" is then sketched between the two sets of points. I haven't had time to write up this topic but perhaps this quick description will suffice.

The "spirule" is quite handy if you have quite a few problems to solve, but none are available because of the following costs: $ 30 for a single machine shop model, or 50¢ each for a stamped version in a lot of 500. It's not worth $30 and the demand is far short of 500. Meanwhile, I suggest that the classroom problems be limited to estimates of angles and vector lengths. If you do this, I'd like to know how broad a spread in answers is obtained for the same problem.

Yours very truly,

Walter R. Evans

1706 Maple.St.
Whittier , Cal.
April 8, 1950

Professor R.C.H. Wheeler
U. S. Naval Postgraduate School
Annapolis, Maryland

Dear Professor Wheeler:

Thank you for your interest in the root locus idea. As you may recall at the AIEE meeting, approximately 70 indicated an interest in obtaining a spirule. Since then only 3 persons have written. This presents the following problem in costs: $30 each for a machine shop model, 50¢ each for a stamped model in a lot of 500. The spirule is worth $30, and the demand is far short of 500! It looks therefore as if they won't be manufactured until some intermediate method is found or until I finish writing a book in which the spirule is to be enclosed.

Meanwhile, I believe that much can be learned, particularly in classroom work, by working problems in which the angles needed for the locus are just estimated by eye. Most problems have enough special points that the total angle will be correct to within 10°. The product of line lengths needed for computing the gain at any point can probably be estimated to within 20%.

You may have occasion to suggest some research projects to some of your students, so here are a few that are not even mentioned in the paper The locus of roots line is the same as a flux line in an electric field in which a charged wire is placed at each pole and a charged wired of opposite sign is placed at each zero. Multicoupled systems are often better handled by determinant expansion than by block diagram manipulation. Thus the locus versus C of a lead network mentioned in the talk can be proved by the fact that the characteristic determinant can be expanded in the form:
$(1 - s/p_1)(1 - s/p_2)(\ )\cdots + C(1 - s/q_1)(1 - s/q_2)\cdots$

The p_i points are the roots for $C = 0$ and the q_i points are the roots for $C = \infty$. The value of C appears as a "loop gain" when the sum of the two terms above is made zero by making the ratio of the terms -1. On and on it goes, I've found that this simple idea has asked more questions than it has answered.

Sincerely yours,
Walter R. Evans
Walter R. Evans

P.S. Give my regards to Dean Glasgow; -- he taught me all about back at Washington U.

1706 Maple St.
Whittier, Cal.
April 8, 1950

Professor W.E. Meserve
Dept. of Electrical Engineering
Cornell University
Ithaca, N. Y.

Dear Professor Meserve:

Thank you for your interest in the root locus idea. As you may recall at the AIEE meeting, approximately 70 indicated an interest in obtaining a spirule. Since then only 3 persons have written. This presents the following problem in costs: $30 each for a machine shop model, 50¢ each for a stamped model in a lot of 500. The spirule isn't worth $30, and the demand is far short of 500! It looks like they won't be manufactured until some intermediate method is found or until I finish writing a book in which the spirule is to be enclosed.

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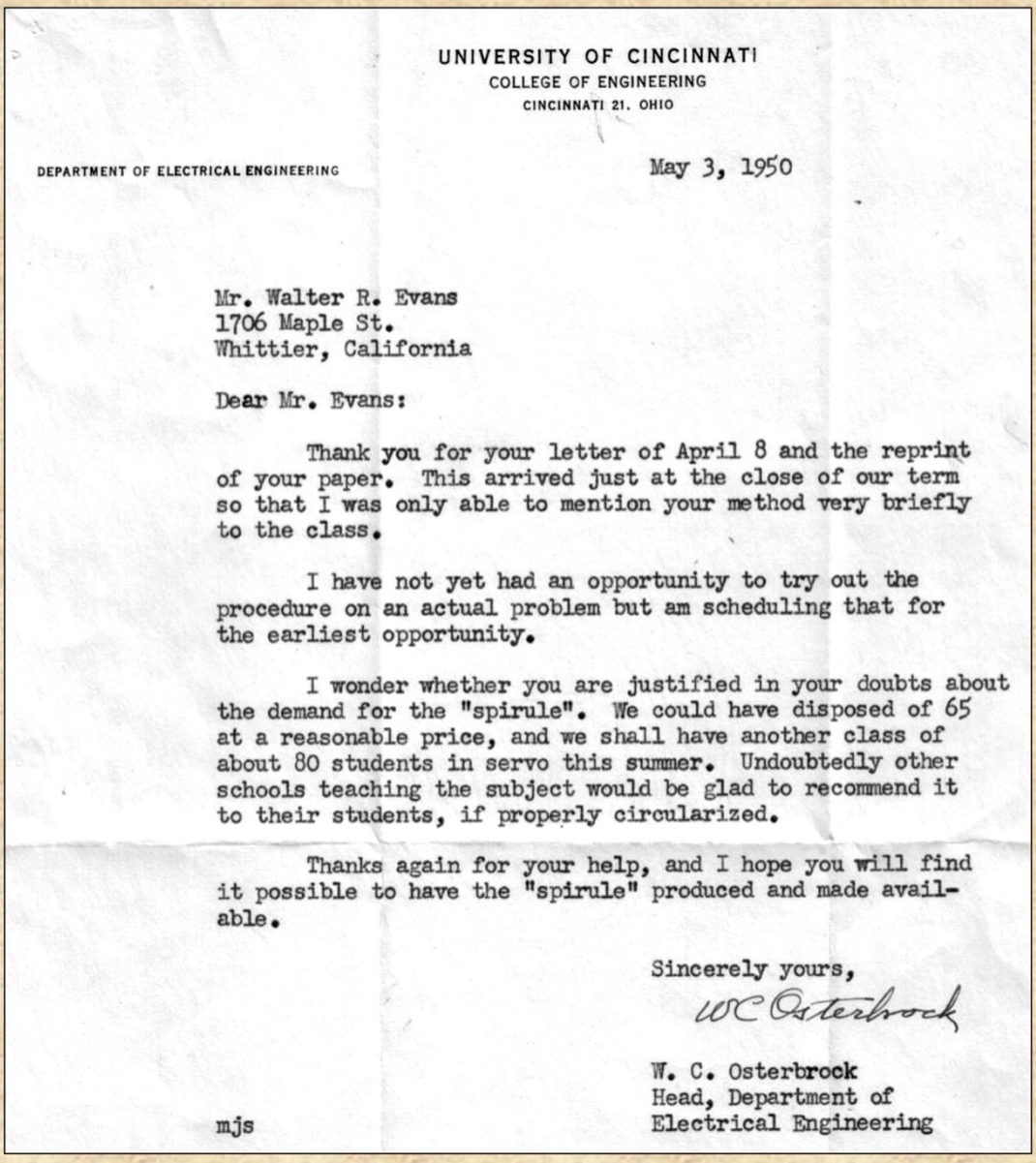
Yours very truly,

Walter R. Evans

April 1949: Walt's response, "It's not worth $30 and demand is far short of 500."

W.C. Osterbrock, head of the Department of Electrical Engineering at the University of Cincinnati, responded by telling Evans

"I wonder whether you are justified in your doubts about the demand for the "spirule". We could have disposed of 65 at a reasonable price, and we shall have another class of about 80 students in servo this summer."



UNIVERSITY OF CINCINNATI
COLLEGE OF ENGINEERING
CINCINNATI 21, OHIO

DEPARTMENT OF ELECTRICAL ENGINEERING

May 3, 1950

Mr. Walter R. Evans
1706 Maple St.
Whittier, California

Dear Mr. Evans:

Thank you for your letter of April 8 and the reprint of your paper. This arrived just at the close of our term so that I was only able to mention your method very briefly to the class.

I have not yet had an opportunity to try out the procedure on an actual problem but am scheduling that for the earliest opportunity.

I wonder whether you are justified in your doubts about the demand for the "spirule". We could have disposed of 65 at a reasonable price, and we shall have another class of about 80 students in servo this summer. Undoubtedly other schools teaching the subject would be glad to recommend it to their students, if properly circularized.

Thanks again for your help, and I hope you will find it possible to have the "spirule" produced and made available.

Sincerely yours,

WC Osterbrock

W. C. Osterbrock
Head, Department of
Electrical Engineering

mjs

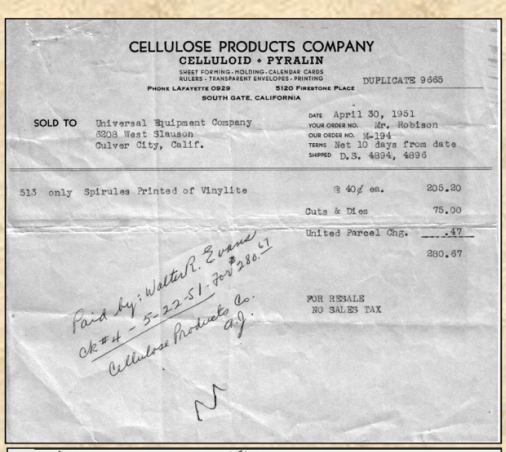
May 1949: W.C.Osterbrock Feedback: "I wonder whether you are justified in your doubts?"

Walt paid $280.67 for an initial manufacturing run of 513 spirules.

From October 1 through December 31, 1951, Evans sold a grand total of 46 spirules.

The first college sales were to Caltech's Charles Wilts (2) and MIT's Edward Samario (5)
.

From these modest beginnings , Arline and Walter kept the letters and purchase orders for every Spirule ordered over the decades to come



CELLULOSE PRODUCTS COMPANY
CELLULOID • PYRALIN
SHEET FORMING - MOLDING - CALENDAR CARDS
RULERS - TRANSPARENT ENVELOPES - PRINTING
Phone LAFAYETTE 0929 — 5120 Firestone Place — DUPLICATE 9665
SOUTH GATE, CALIFORNIA

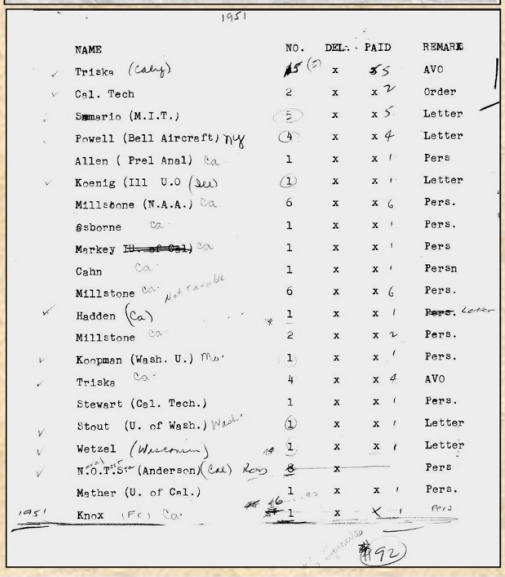
SOLD TO Universal Equipment Company
8023 West Sllauson
Culver City, Calif.

DATE April 30, 1951
YOUR ORDER NO. Mr. Robison
OUR ORDER NO. 4-294
TERMS Net 10 days from date
SHIPPED D.S. 4894, 4896

513 only Spirules Printed of Vinylite	@ 40¢ ea.	205.20
	Cuts & Dies	75.00
	United Parcel Chg.	.47
		280.67

Paid by Walter R. Evans
Ck #4 - 5-23-51 - for $280.67
Cellulose Products Co.

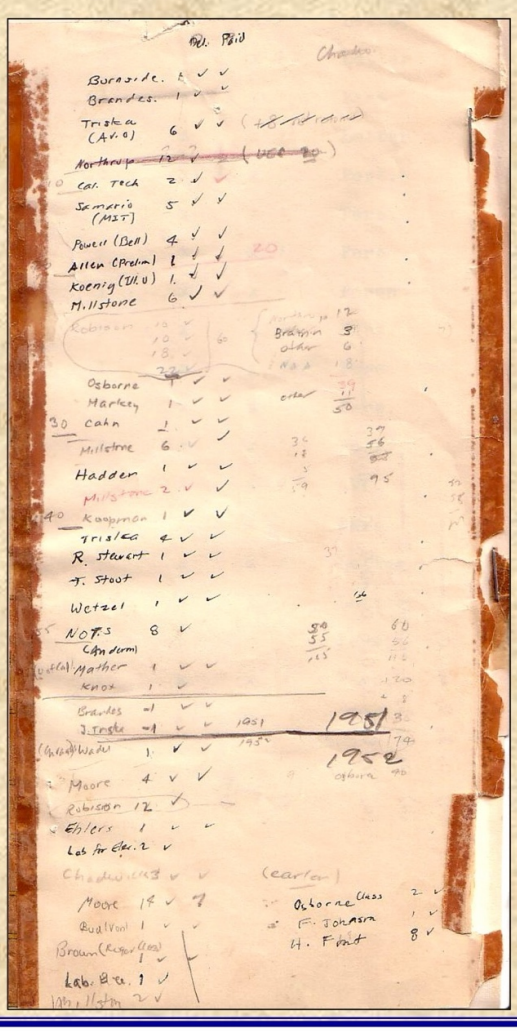
FOR RESALE
NO SALES TAX



1951

	NAME	NO.	DEL.	PAID	REMARK
✓	Triska (Calif)	~~15~~ (5)	x	~~55~~	AVO
✓	Cal. Tech	2	x	x 2	Order
	Samario (M.I.T.)	(5)	x	x 5	Letter
	Powell (Bell Aircraft) NY	(4)	x	x 4	Letter
	Allen (Prel Anal) Ca	1	x	x 1	Pers
✓	Koenig (Ill U.O (Ill)	(1)	x	x 1	Letter
	Millstone (N.A.A.) Ca	6	x	x 6	Pers.
	Osborne Ca	1	x	x 1	Pers.
	Markey ~~Ill. of Cal.~~ Ca	1	x	x 1	Pers
	Cahn Ca	1	x	x 1	Persn
	Millstone Ca	6	x	x 6	Pers.
✓	Hadden (Ca)	1	x	x 1	~~Pers.~~ Letter
	Millstone Ca	2	x	x 2	Pers.
✓	Koopman (Wash. U.) Mo	1	x	x 1	Pers.
✓	Triska Ca	4	x	x 4	AVO
	Stewart (Cal. Tech.)	1	x	x 1	Pers.
✓	Stout (U. of Wash.) Wash	(1)	x	x 1	Letter
✓	Wetzel (Waterman)	(1)	x	x 1	Letter
✓	N.O.T.S. (Anderson) (Cal) Ken	8	x		Pers
	Mather (U. of Cal.)	1	x	x 1	Pers.
1951	Knox (Fr.) Ca.	~~16~~ 1	x	X 1	Pers

#92



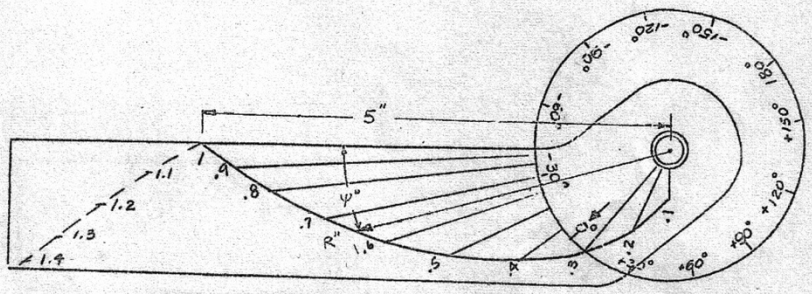
Oct - Dec 1951: NAA makes 513 Spirules. Walt takes orders. Caltech is the first institutional sale.

Evans prepared this letter to serve as an interim instruction sheet for the first batch of spirules.

1706 Maple St.
Whittier, Cal.
October 2, 1951

Dear Sir:

Please pardon the form letter, it is being sent to the large number of engineers who have shown sufficient interest in the Root Locus method of studying control systems to write for North American report AL 787 or the AIEE paper 50-11. The report mentions the possibility of a special plastic device for adding angles and multiplying line lengths and the paper shows a crude model. Sufficient interest has been shown to justify production of the "Spirule"; a photograph appears on p. 594 of the Journal of Aeronautical Sciences September, 1951



Sketch of the "Spirule"

The disk and arm are held together with a light friction fit by an eyelet; a small pin is held in the center of the eyelet by a clear plastic plug. The pin is stuck in the Root Locus plot at the desired s point to form a pivot for all measurements at that point. Recall that all phase angles and vector lengths on the plot have this one point in common. The total phase angle is obtained by rotating the arm with respect to the disk through each of the angles in succession and is read on the disk at the radial edge of the arm.

The spiral curve on the arm is plotted such that the angle $\psi°$ from the radial edge to the curve is proportional to the logarithm of the radius R to that point on the curve as specified by the equation:

$$\psi°/90° = \log_{10}(R"/5")$$

The arm is rotated through each of these angles in succession in order to add logarithms. The numerical value of the product is read on the spiral curve in line with an arrow on the disk subject to the correction x^n, in which x is the numerical value on the plot corresponding to 5" and n is the excess of poles over zeros.

Spirules with instruction sheets can be obtained for $2.00 from the undersigned.

Very truly yours,

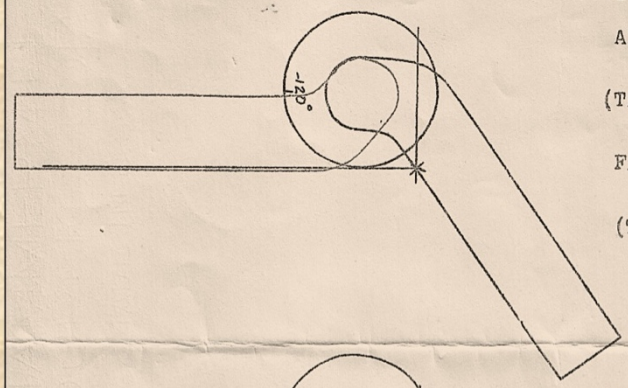
W. R. Evans

W. R. Evans

October 1951: Spirules with instruction sheets could be obtained for $2.00

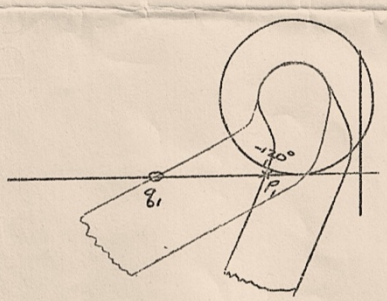
Evans prepared this letter to serve as an interim instruction sheet for the first batch of spirules.

ADDITION OF ANGLES



Set the radial edge of the arm at 0^{o} on the disk
Align the radial edge of the arm with the pole at the origin.
(The Spirule is now as shown in blue.)

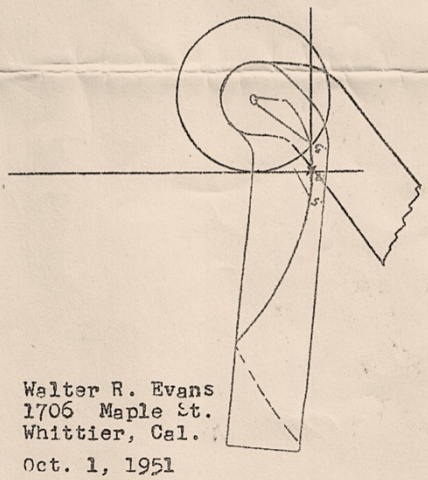
Fix the disk and rotate the arm CW until the edge is horizontal on the plot.
(The Spirule position is now shown in red.) Note that the arm has been rotated with respect to the disk through ϕ_o, which can be read on the disk at the edge of the arm.



Release the disk and align the edge of the arm with the pole p_1.
(Note that the reading on the disk does not change)

Fix the disk and rotate the arm CW until the edge is in line with the zero q_1.
(Note that the reading is thus increased by $(\phi_1 - \phi_o)$
Repeat until all angles have been included.

ADDITION OF LOGARITHMS



Align Spirule as before

Fix the disk and rotate the arm CW until the spiral curve falls on the pole.

(Note that the length s can be read on the spiral curve in line with the arrow on the disk.)

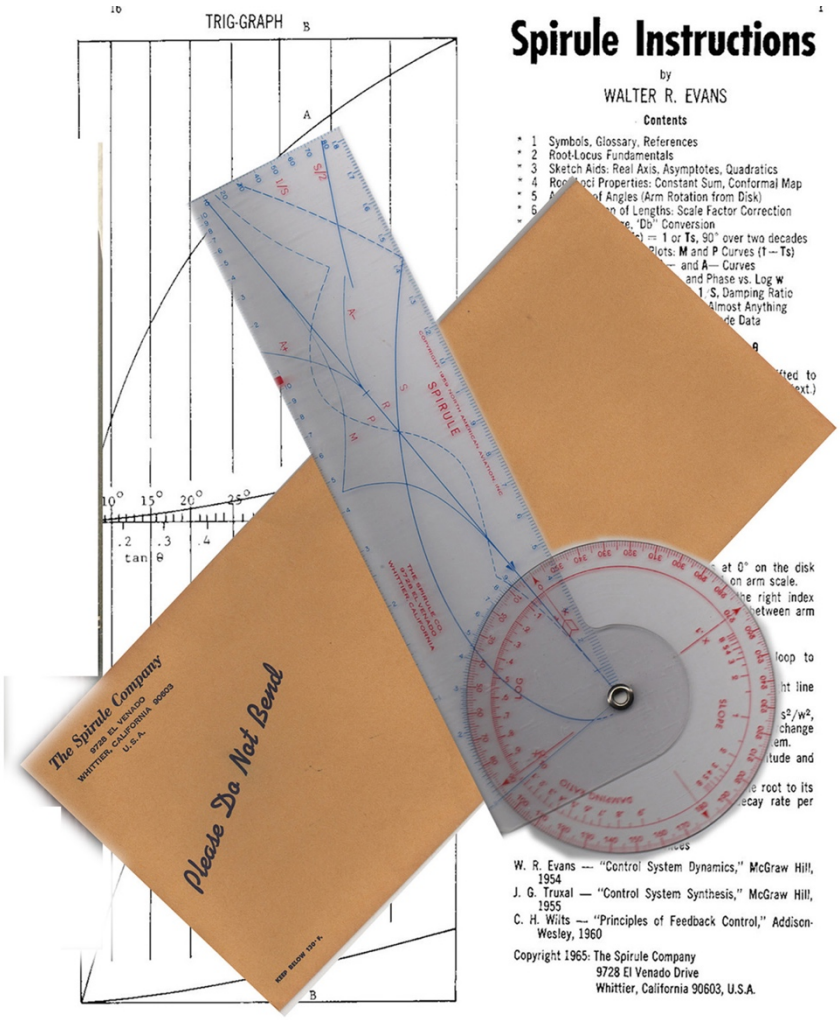
Release the disk before aligning with another zero or pole.

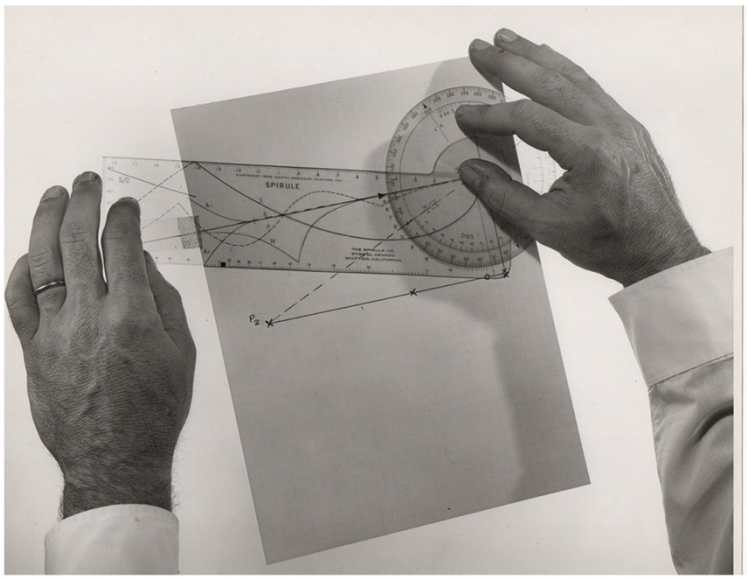
Rotation for zeros is opposite in direction from that for poles.

Walter R. Evans
1706 Maple St.
Whittier, Cal.

Oct. 1, 1951

October 1951: Spirule's use as a circular protractor.





1959 New Model Spirule and Instruction Sheet