American Planimeters[1]

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Figure 1. The Amsler Planimeter.

Introduction

For an introduction to the history of planimeters, see [1].

While there were quite a few interesting area measuring inventions made during the 19th century, it is the Amsler polar planimeter design that came to dominate the marketplace. Jacob Amsler patented his device in 1855 [2].

Figure 1 shows an example of an early Amsler, apparently serial number 83. Note that it does not have a weight at the end of the polar arm. This was added later. It is not signed, but Amsler did not sign his planimeters until quite late in their production. This is a very basic instrument.

Planimeters started to appear in drafting and engineering catalogs in the United States, such as those of Keuffel & Esser. The earliest K&E catalog information in my possession is from 1876 [7]. There is only one planimeter in this catalog, an Amsler. In 1915, K&E published the illustration shown on the back cover. The instruments shown there come from the four major makers: Amsler, Coradi, Haff and Ott[2].

With the major exceptions of radial and linear planimeters[3], these instruments, by and large, are what were available then and are being sold up to the present time. The colors and finishes have changed, and digital/electronic readout was added in some cases, but many of these same planimeters are still in production.

Of particular interest are planimeters employed in the reading of steam engine indicator cards, and radial planimeters employed in the measure of fluid flow, temperature, etc. These will be the main topic in this paper.

LASICO

The Los Angeles Scientific Instrument Company (LASICO) is one of the few remaining makers of planimeters. Founded in 1928 by German immigrants, it produces a fine line of planimeters, integrators and related goods. It will not be considered in this paper, as it merits a story of its own. The company can be found on the internet at www.lasico.com.

Other Internet Sites

Gebruder Haff has been on the internet, but I was unable to bring up their site (haff.de/planimeter.htm). Both nax.com/kunkel/planimeter and xbasic.com/ljl/planimeter/index.htm have interesting material on the subject.

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[1] This paper was given as a talk at Greifswald, Germany in 2000.

[2] For a discussion of Ott planimeters, see [5]. Dennert & Pape made planimeters for a short time before the turn of the century, but dropped them after a few years. There planimeters do not appear to have been marketed by K&E, although their slide rules were for a while before K&E began to start their own production. Perhaps some other US company did sell them, as at least three of them have been found in the US.

[3] Another category, *hatchet planimeters,* does not appear to have caught on in the US as it did in Europe.

The Steam Engine Problem.[4]

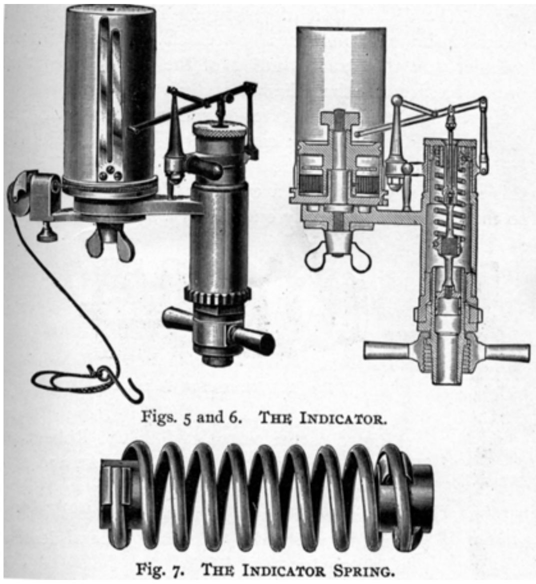

Figure 2. The Steam Engine Indicator

The above illustration is taken from [6], page 11. It shows a typical steam engine indicator from around 1900. The indicator is a device attached directly to the cylinder of a steam engine for the purpose of measuring the *mean engine pressure,* or MEP. From this, and the physical parameters of the engine, the horsepower of the engine could be calculated. It also served to diagnose various problems with the engine. It is generally attributed to James Watt, although it is not mentioned in [4]. Watt did conceive of both the idea of horsepower for his engines and pressure gauges to measure the pressure in the boiler, cylinder, etc., and it is reasonable to suppose that he generalized this to the mechanization of the computation of the mean pressure.

The indicator works as follows:

- The instrument comes with a set of springs (usually six). Each of these corresponds to a range of pressure values of interest. A chosen spring is inserted into the cylinder of the instrument, which is on its right-hand side in the illustration. That cylinder is screwed into the cylinder of the steam engine.
- In operation, the steam in the engine forces the small piston in the indicator cylinder up and down.
- The indicator cylinder is connected via a parallel motion mechanism to a pencil. This writes on a paper "card" which has been placed on the drum on the left-hand side of the instrument.
- The drum can rotate, but it is held in place by a spring. There is a string wrapped around the drum. The other end of the string has a hook on it.
- The hook is indirectly attached to the engine piston, so that as the piston moves back and forth, the drum rotates back and forth, recording the engine pressure on the card.

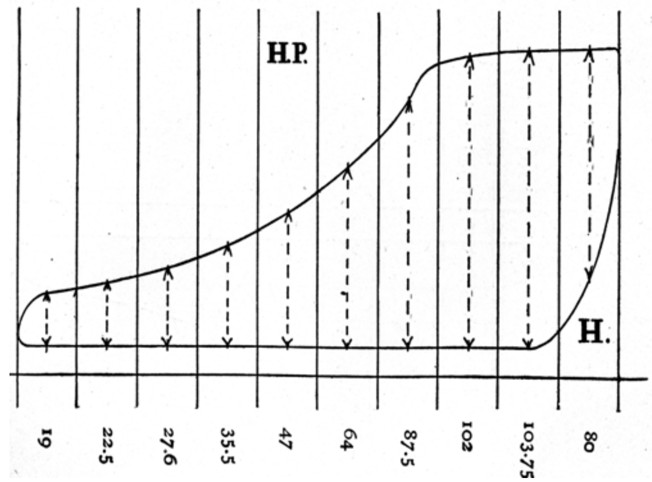

Figure 3. Sketch of a card produced by the indicator.

Figure 3. shows the sketch from [6] of a card produced by an indicator. Superimposed on the curve produced by the indicator are lines used to provide an estimate of the MEP. Special, non-planimeter, instruments were made to facilitate this integration estimate based on drawing vertical lines at equal intervals on the diagram. The distances between the top and bottom of the dotted lines are measured and averaged to form an estimate of the MEP.

Movement around the diagram is counterclockwise. The x-axis is stroke length, the y-axis is pressure. The indicated calculation produced an MEP of 58.885 pounds per square inch.

As an example of the horsepower computation, suppose the piston diameter is 12 in., its stroke is 3 ft., the engine is operating at 112 revolutions per minute, and the indicated MEP is 52.87 pounds per square inch. Then the indicated horsepower is:

$$IHP = \frac{(\pi \times 6^2 \times 52.87) \times (3 \times 112 \times 2)}{33,000} = 122$$

The approximate averaging done in the example would be time-consuming, error-prone and much less accurate than the four and five figures given in the results for MEP in the above examples. A planimeter would do a better job. Amsler planimeters were no doubt used for this purpose. In fact, Amsler introduced a modified polar planimeter with two points protruding from the pole arm. This allowed the pole to be adjusted to the length of the diagram and facilitated the calculations. These were sold by W.F. Stanley of London and the Crosby Steam Gauge and Valve Co. of Boston.

These were very finely made and no doubt expensive instruments, perhaps too expensive for the taste of the

[4] For a more detailed explanation of this topic, see [10].

American market. In any event, cheaper American-made instruments began to appear. They could be cheaper because they were made for relatively small areas, and hence do not require a secondary wheel to count revolutions of the main wheel. Also, there would be no import duty to pay.

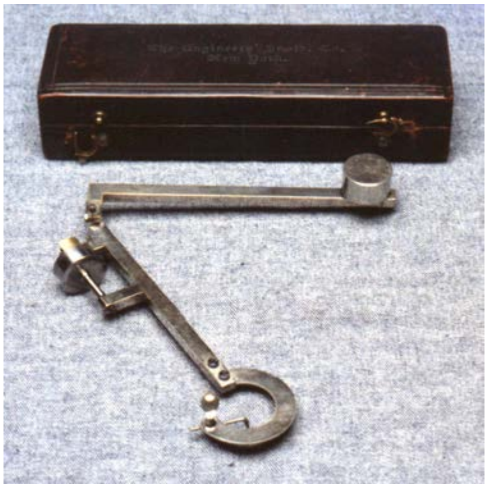

Figure 4. Engineers' Inst. Co. N.Y.

Such an instrument is shown above. Note that the appearance of having been made in the USA does not necessarily imply that it was. Many of the planimeters sold by K&E, especially those made by Haff, did not carry any reference to their being foreign made. However, this one does not show characteristics of the Swiss and German makers. It is small and does have a limited range, making it appropriate for steam engine indicator work.

At least five planimeters that were made for reading indicator cards are very likely American. These include the following:

- The Willis planimeter. Figure 5.
- The Trill planimeter. Not shown.
- The Lippincott planimeter. Figure 6.
- The Ashcroft planimeter. Figure 7.
- The Bushnell-Coffin planimeter. Not shown.

The Willis, Trill, and Lippincott can be viewed as one group, and the Ashcroft and the Bushnell-Coffin planimeters as a second.

The first three are free-standing instruments, all having a circular knife-edged wheel that can move freely back and forth on a bar perpendicular to the pole bar. They read directly from the difference between the start and stop positions of the sliding circular knife.

The Willis is shown in Figure 5. It was designed by Edward Jones Willis [9], and manufactured by James L. Robertson & Sons Co. of New York. Willis was a steam engineer in Richmond, Virginia. The example shown carries three patent numbers: US 529,008 (1894, reissued in 1896), US 672,581 (1901) and the Lippincott US patent 569,107 (1896). It was also patented in the UK: 672,581 (1901). In the 1930s Willis wrote and invented in the area of navigation [3].

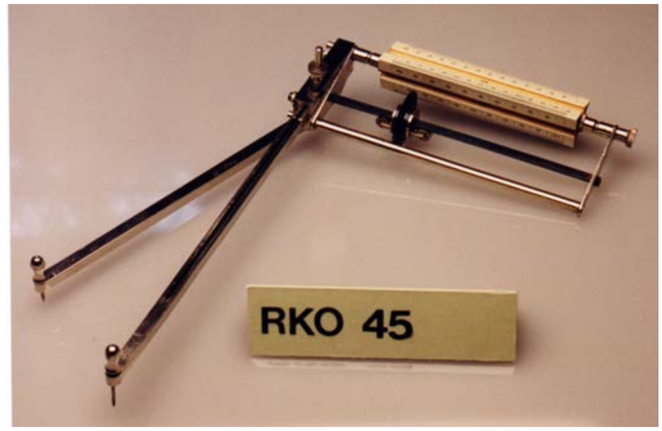

Figure 5. Willis Planimeter ca 1901

The circular knife is carried by a small trolley along the central rod. The knife is said to rotate on ball bearings. The triangular rule has six scales and the pole arm is adjustable and is calibrated. Thus, it is possible to set the device up to read directly in the desired units, especially if the scales correspond directly to the springs.

The Trill is somewhat similar to the Willis in that it also has a circular knife edge and has triangular scales. It differs as follows: it has two such scales rather than the single one on the Willis; the circular knife attached to the center of a 7.5-inch rod that slides on small wheels; instead of reading from the knife edge, the two triangular rules are on the opposite side of the instrument from the knife, and there are pointers attached on the other side of the rod carrying the knife used for reading.

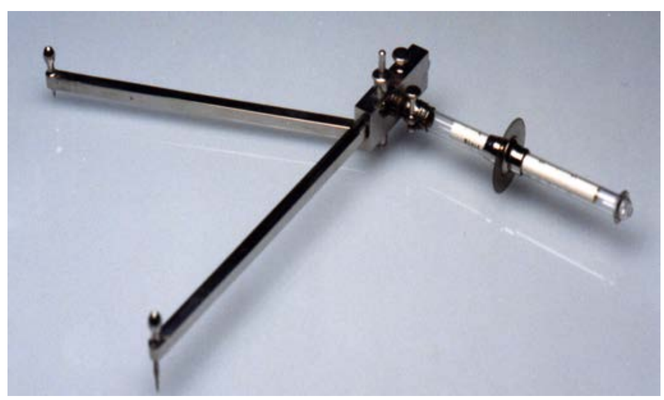

Figure 6. Lippincott planimeter.

The planimeter designed by Alpheus C. Lippincott of New York City is rather unique, even in this first group of strange instruments. It was made by the Hine & Robertson Co., N.Y., presumably the successors to James L. Robertson & Sons Co. of New York. The basic structure of the Willis and the Lippincott are the same, with one major difference: the circular knife blade, rather than being mounted on a trolley which slides on a metal bar, merely slides on a glass tube. The tubes (there are three supplied with the instrument) are about 4.5 in. long and about 0.353 in. in diameter. Each tube carries two scales for reading the area, for a total of six available to the user. On two of the glass tubes the knife slides freely, a necessity for the device to work properly; on the third tube the knife does not move easily, and thus the instrument would not be functional.

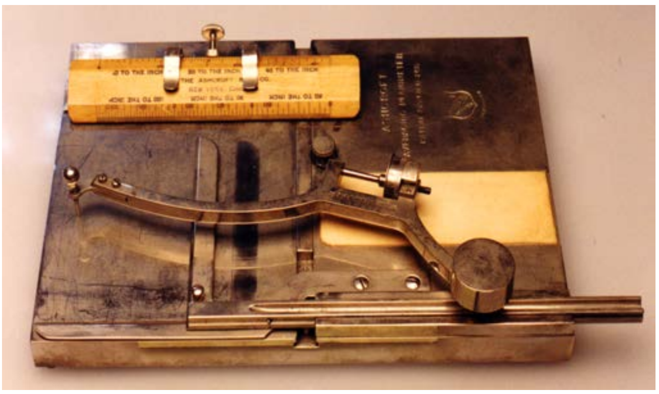

Figure 7. The Ashcroft planimeter.

The second group of planimeters made for reading steam indicator cards is radically different from almost every other planimeter made:

- They are *linear* rather than polar planimeters. That is, one end of the mechanism slides along in a long slot.
- They are small but heavy.
- The have an integral bedplate, 5.5 × 7.7 in. in the case of the Ashcroft.
- The readout wheel rests on a pad shown on the right side of the illustration.
- The indicator card (not shown) is clamped on the left.

The example shown has everything required for operation stowed in one case. It can be set up and worked in a small area independent of having a flat table on which to work. Overall, it is a very well made instrument. In another partial example the arm with the reading wheel was found by itself in its own case. As it is not usable without the baseplate, it was somewhat of a mystery at the time.

The Bushnell-Coffin planimeter was made by the American Steam Gauge and Valve Co. of Boston. It is similar to the Ashcroft, but is somewhat smaller and lighter, with the ruler (in this case it is circular in form) attached to the bedplate. The principal difference is that the arm with the wheel does not slide in a slot; rather, there is a rod attatched to the bedplate with a small slide riding on it. The end of the arm fits into the slide. The effect is the same. Like the Ashcroft, the whole set fits into its own case.

Radial Planimeters

Radial planimeters are the second category that is considered in this paper. In their basic form, they are quite simple. The planimeter sits in the middle of the area being computed (just the opposite of the polar, which must be outside of it) and has an arm that turns in a full circle.

This type of planimeter has a number of purposes. One application, not considered here, is that of measuring the area of a large piece of leather. It is convenient to be able to put the instrument in the middle of the hide rather than off to one side, as both the hide and the instrument can be quite large.

The principal type of instrument to be considered was designed for the application of reading circular charts produced by a variety of recording instruments. Such meters record temperature, barometric pressure, fluid flow, etc., on a chart on the order of one foot in diameter. One revolution of the chart on the meter usually corresponds to a specified length of time such as an hour, a day, or a week.

Such a planimeter can be used to obtain the average value of the temperature for a week, or the total amount of fluid flow for some standard period of time.

Note that while I have a fair number of radial planimeters in my collection, only in one case do I have the corresponding printed chart. Without the chart, it is not always obvious just what sort of calculation is being performed by the planimeter.

The first patent for a radial planimeter in the US was number 927,338, granted July 6, 1909. It was issued to William Frederick Durand.

Figure 8. The Durand radial planimeter.

The planimeter shown in Figure 8, while bearing the Durand name and patent number, was made in Switzerland by Amsler. It also has the company name of The Industrial Instrument Co., Foxboro, Mass., USA.

Durand had an incredibly long career. The following was taken from a Stanford University document:

> "Fresh out of Annapolis in 1880, he was assigned to the USS Tennessee, Flagship of the North American Fleet. She was wood hulled and full rigged, but Durand's job was to look after the steam engine that took over when

the wind failed. He left the navy in 1887 for the academic world, and his research at Cornell University eliminated the guesswork from the design of marine screw propellers.

After coming to Stanford University in California in 1904, Durand applied his background in fluid mechanics to the water and power problems of the Western states. But with the development of the airplane his old love of propellers returned and his long series of experiments in a Stanford wind tunnel became the authoritative source for their design.

During World War I Durand—a slightly built, bearded scholar—played a leading part in the development of military aircraft. In 1917 he was one of the first three engineers elected to the National Academy of Science.

Durand returned to Stanford shortly after the armistice and reached retirement age in 1924. Thereupon began a remarkable sequence of service on high government commissions – among them the integration of aircraft in national defense (after the Gen. Billy Mitchell scandal), feasibility of the Hoover Dam, and fish ladders for the Grand Coulee Dam. But most remarkable of all was his call to Washington in 1941, when he was 82, to head the development of jet propulsion for application to aircraft. The first US jet plane was test-flown in 1942.

Durand died in 1958 at the age of 99."

There is a building at Stanford named for him.

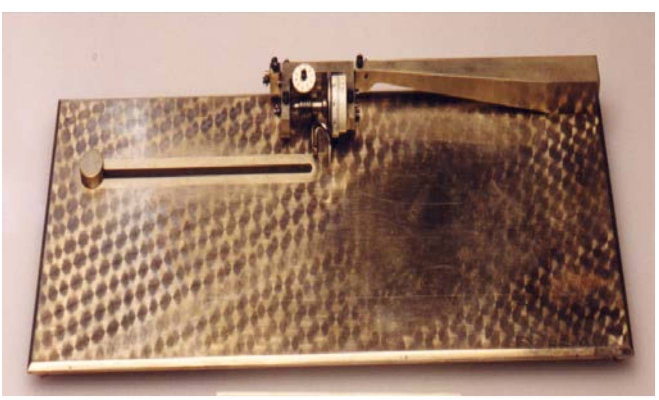

Figure 9. A Foxboro linear radial planimeter.

The Foxboro Instrument Company of Foxboro, Mass. is still in existence. I have not been able yet to find a connection with Durand. They are now a major maker of flow metering devices. However, they no longer appear to make planimeters. The Foxboro planimeter shown in Figure 10 is linear.[5] The hole in the middle of the circular chart is placed over the button shown to the left of the slot, and slides under the bar on the right that holds the recording mechanism. The chart can simultaneously be turned and also be moved from left to right by the operator taking the reading. In use, the operator places the start of the trace to be integrated under the pointer near the recording wheel, and manipulates the chart, so that while it makes a complete revolution the pointer is always on the trace being analyzed. This planimeter could be used for computing the average temperature from a circular temperature recorder.

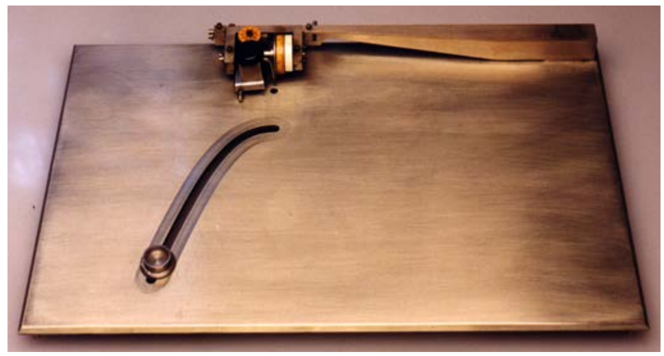

Figure 10. A Foxboro square root radial planimeter.

The square root planimeter is mainly used for integrating (summing) fluid flow for a given period of time. The recording instrument essentially measures pitot tube pressure. The square root of this is proportional to the velocity of the fluid, and the integral of the velocity, properly scaled to the size of the pipe containing the fluid, yields the total amount of fluid that has passed through the metering device during the time of recording.

The problem with the planimeter shown is that it is made for a single specific chart. It is not a general instrument. Indeed, the peculiar curve on the instrument had to be redone for every new recorder and its chart. All of the various makers of this type of planimeter had to be prepared to produce an updated square-rooting curve when a new and different recording meter came on the market.

The mechanism for the Bailey Meter Co. planimeter is shown in Figure 11. The instrument at one time had a large bedplate with a central pole. The chart to be read would fit over the pole, and the planimeter then put on top of both. There is a cam on the top of the planimeter held in place by two large screws. It performs the function of computing the square root. The instrument comes with three different cams. This portion of the whole device alone is quite massive by itself. The Bailey Meter Co. was located in Cleveland, Ohio.

Changing the position of the tracing arm turns the cam; shown at the edge of the cam is a pin that turns the angle of the recording mechanism in order to achieve the desired square root adjustment to the measurement.

[5] Note the different use of the word linear here.

Figure 11. A Bailey Meter Co. Planimeter (without bedplate).

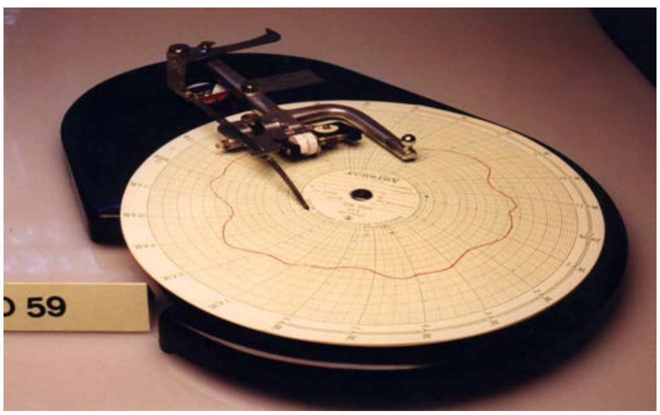

Figure 12. An American Meter Co. non-radial planimeter.

The American Meter Co. is still in business, though it is not clear that they are now making planimeters such as the one shown in Figure 12. Like Foxboro, they appear to have gone to direct digitization of the quantities of interest.

The chart shown on the instrument is just under 12 in. in diameter, and is for a 24-hour recording period. While it is a circular chart, the planimeter action is not radial. Rather, the arm is pivoted at the top of the instrument so as to mimic the action of the original recording pen. The cam at the top of the instrument performs the square root operation.

The best description that I can come up with, is that it is "like a linear planimeter, only in circular form with a square root action".

The gentleman from whom I obtained the planimeter told me that the instrument was entirely made by the American Meter Co., *except for the integrating mechanism, that was taken from an ordinary planimeter sold by K&E.* He told me that they bought the planimeters in quantity, took off the recording devices, and then threw away the remaining parts!

In Conclusion

A large number of planimeters were and are being manufactured in the US. The business started before 1900, in the case of those mainly used for reading steam indicator cards, and perhaps around 1910 for the ones employed in reading circular charts.

It is clear that perhaps some of the parts and, in some cases the whole instrument itself, came from suppliers in Europe. This may have been a problem in WWI. The establishment of LASICO in 1928 mitigated the problem in WWII.

Planimeters are still being used in activities varying from swimming pool cost estimation to computing fluid flow. Area finding is not yet something that a computer can do readily. No doubt that will change.

Acknowledgement

I should like to thank Prof. Dr. Joachim Fischer for all of the help and information that he has given to me over the years. Note that I am solely responsible for any errors and misinformation that may be found in the above.

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