Nov. 16, 1948. I. GOLDFIEN 2,454,157

SEWER DESIGN SLIDE RULE

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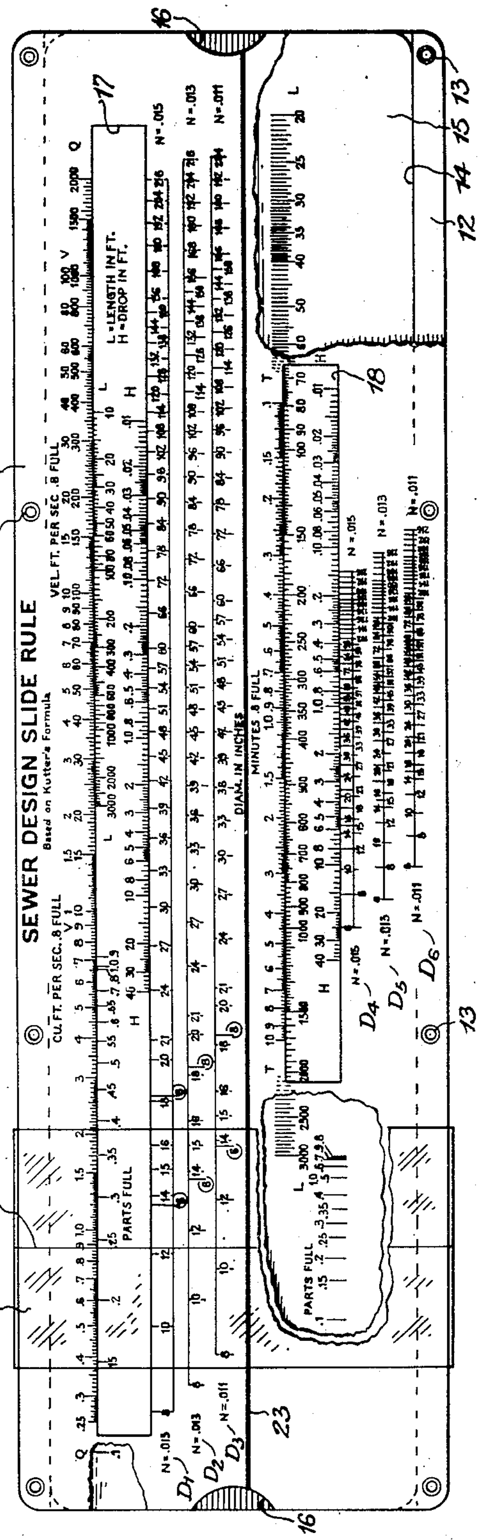

FIG. 1

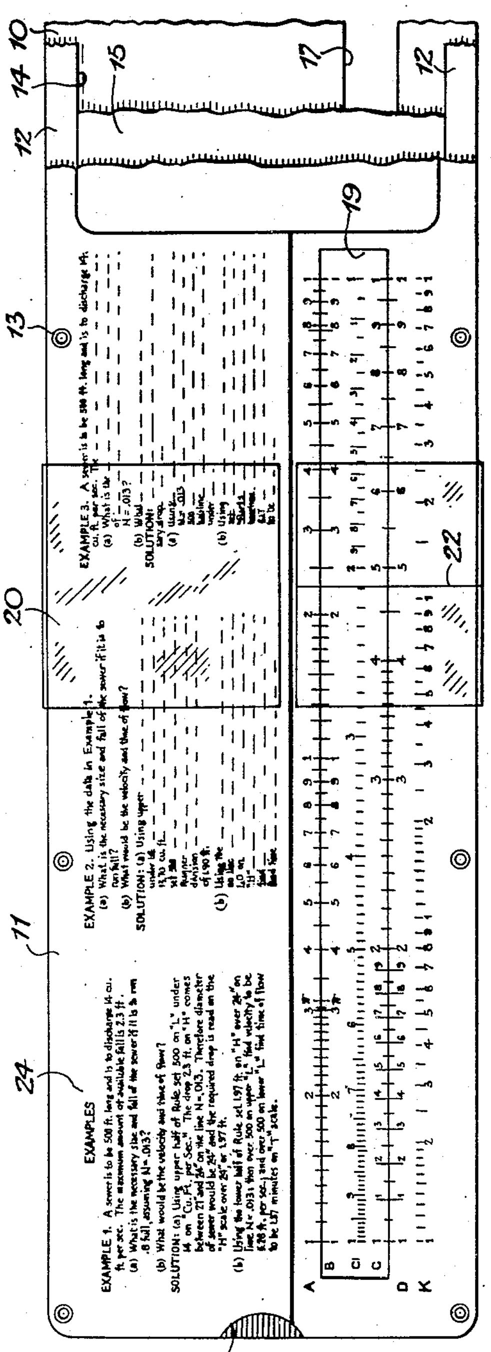

FIG. 2

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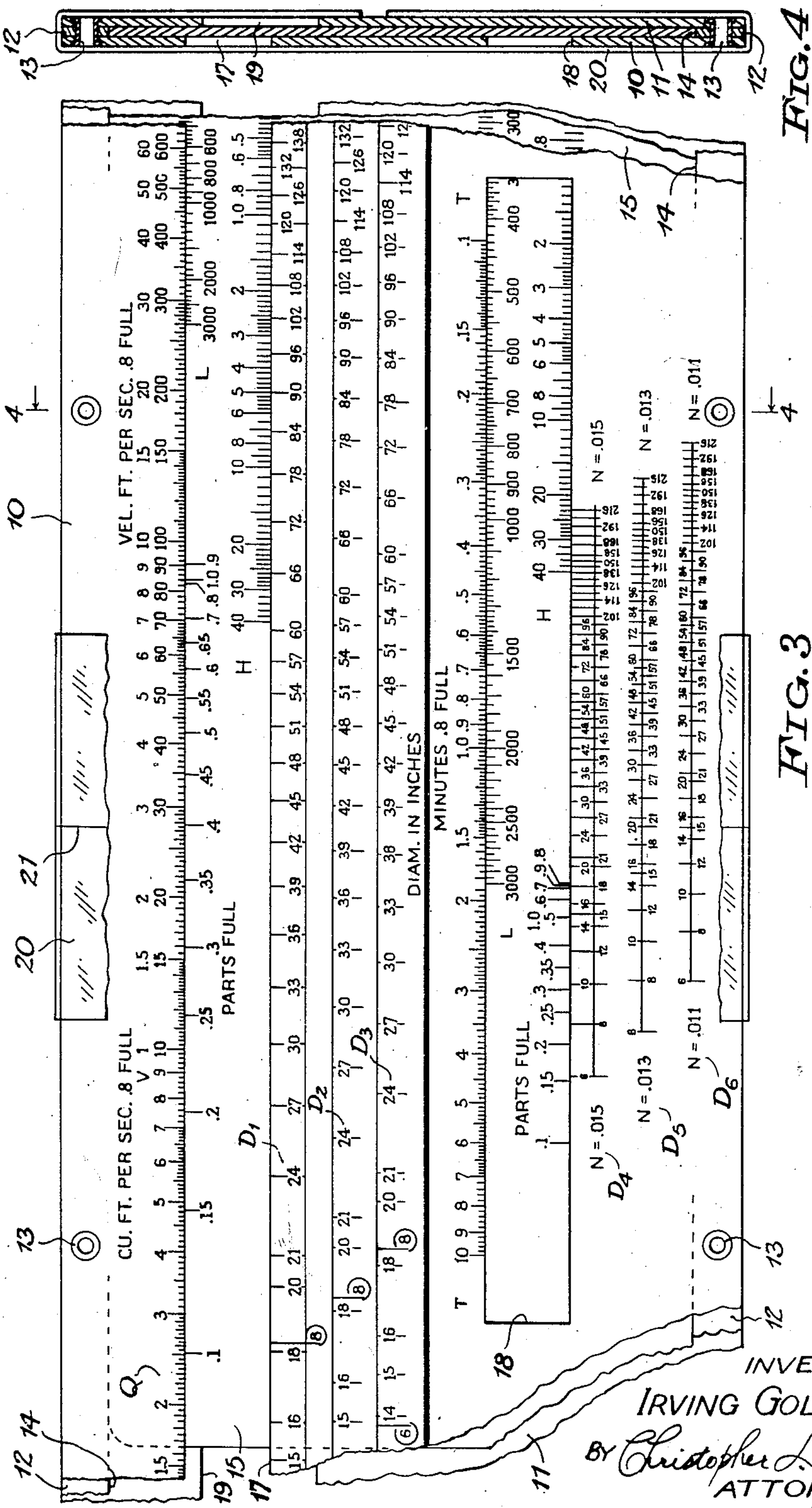

FIG. 4

FIG. 3

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SEWER DESIGN SLIDE RULE

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5 Claims. (Cl. 235—70)

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The present invention relates to slide rules and more particularly to those for solving problems in sewer design.

The Chezy formula, $V=C\sqrt{RS}$, for water flow in pipes and channels, is known as the Kutter formula when for C is substituted an expression depending on the roughness of the channel, the slope S and the hydraulic radius R, i. e., the cross-sectional area divided by the wetted perimeter. The usual Kutter expression for C, in English measure, is

$$\frac{41.67+\frac{1.811}{N}+\frac{0.00281}{S}}{\left(1+41.67+\frac{0.00281}{S}\right)\frac{N}{\sqrt{R}}}$$

in which N is the Kutter coefficient of roughness or friction, this coefficient or factor increasing with roughness. The values of N used in sewer design ordinarily range from .011 to .015, although lower and higher values are occasionally encountered.

The elements or factors involved in the design of circular sewers are: Q, the quantity of flow in cubic feet per second; N, the friction factor; D, the diameter of the sewer pipe in inches; L, the length of the pipe in feet; H, the drop of the pipe in feet; "Parts Full," the relative depth of flow in the pipe; V, the velocity of flow in feet per second; and T, the time of flow in minutes. When any five of these eight elements are known, the values of the other three elements can be determined.

An object of the invention is to provide an improved and simply operated sewer design slide rule based on the Kutter formula and arranged for quickly and accurately solving a wide variety of problems involving circular sewers.

Another object is to provide a sewer design slide rule which includes accurate and easily readable scales of wide range while being of a handy size, a typical length of the new rule being about 13 inches which permits the device to be conveniently carried in a pocket or brief case for field use.

The invention further consists in the several features hereinafter described and claimed.

In the accompanying drawings,

Fig. 1 is a plan view showing the front face of a slide rule constructed and arranged in accordance with the invention, parts being broken away;

Fig. 2 is a plan view showing the rear face of the slide rule, parts being broken away;

Fig. 3 is an enlarged plan view showing the middle portion of the front face of the rule, parts

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being broken away and a slide member of the rule being shifted to the right, and

Fig. 4 is a transverse sectional view of the slide rule, taken on the line 4—4 of Fig. 3.

In the drawings, the numerals 10 and 11 respectively designate rectangular front and rear frame plates which are separated by longitudinal marginal strips 12, the plates and strips being secured together as by countersunk tubular rivets 13. The frame assembly or body thus formed presents a longitudinal slot or passage 14 receiving and guiding therein a plate-like slide 15, the ends of the frame plates having notches 16 to facilitate longitudinal displacement of the slide. The front frame plate 10 has elongated rectangular upper and lower windows 17 and 18, respectively, and the rear frame plate 11 has an elongated rectangular window 19, all the windows extending parallel to the upper and lower edges of the frame plates. A runner 20 slidably embraces the frame assembly, and by way of example may be formed of a transparent sheet of plastic material, such as cellulose acetate, having thereon a front hairline 21 and a rear hairline 22 each extending at right angles to the windows.

The front of the slide rule is divided into upper and lower rule sections or halves, hereinafter described, by a heavy horizontal line 23 on the front frame plate, the windows 17 and 18 being respectively disposed in these sections.

The front frame plate has printed or engraved thereon above and along the upper window, 17, a logarithmic quantity scale Q and a logarithmic velocity scale V, the Q scale (designated "cu. ft. per sec. .8 full") being in cubic feet per second and ranging from .25 to 2000 cubic feet, left to right, and the V scale (designated "vel. ft. per sec. .8 full") being in feet per second and ranging from 1 to 100 feet, left to right. Each member on the V scale coincides with a number ten times as large as the Q scale. If desired, these scales may be printed in contrasting colors.

Below and along the upper window, 17, the front frame plate has several parallel scales D_1, D_2, and D_3 of circular pipe sizes, designated "diam. in inches," for different Kutter N coefficients, here shown for N=.015, N=.013, and N=.011, the pipe sizes ranging from 8 to 216 inches in diameter and increasing from left to right. The N coefficients given are those most commonly used, being for brick, concrete and vitrified clay sewer pipes; however, additional or substitute D scales may be provided for larger or smaller N coefficients. For extremely smooth pipes, such as those of asbestos-cement, the value of N ranges from .009 to .011, while for corrugated steel pipes the value of N ranges from .015 to .021. Each of the D scales has additional indices for pipes of 6 inch and 8 inch diameter, these indices being the encircled numbers 6 and 8 and being so located as to permit computations for pipes of 6 inch diameter without extending the length of the slide rule. These computations will involve multiplication or division by 10 of the given or found Q values. The D scales are offset to the left with increasing value of N. By way of example, a 48 inch pipe on the scale N=.015, corresponds approximately to a 45 inch pipe on the scale N=.013 and a 42 inch pipe on the scale N=.011.

Along its upper portion the slide has several scales visible through the window 17 and associated with the adjacent scales on the front plate to form the upper rule section. These slide scales consist of a length scale L, a drop scale H therebelow, and a "parts full" scale at the left of the L scale. The L scale, which is for the length of the sewer in feet, ranges from 3000 to 10, left to right; the H scale, which is for the drop of the sewer in feet, ranges from 40 to .01, left to right; and the "parts full" scale ranges from .1 to 1, left to right. The "parts full" scale and the L scale extend along the upper edge of the window 17, and the H scale extends along the lower edge of this window. The scales of the upper rule section are adjusted for the sewer running .8 full, a point when the velocity is practically the greatest and the discharge about 98% of the discharge running full. The "parts full" scale is provided for converting the discharge for other depths of flow on the upper scales. It will be noted that in the "parts full" scale the number 1.0 is placed between .8 and .9 and is close to .8. This relation reflects the fact that in a circular pipe the flow running .8 full is nearly as large as the flow running full, and that the maximum flow occurs with the pipe running about 93% full. A margin of carrying capacity is thus provided.

Above and along the lower window, 18, the front plate has a logarithmic time scale T, designated "minutes .8 full," ranging from 10 to .1, left to right, and being based on a pipe flowing .8 full. Below and along the window 18 the front frame plate has several parallel scales D_4, D_5, D_6, of circular pipe sizes, for different Kutter N coefficients, arranged in the same general manner and for the same values of N as the D scales of the upper rule section, but being somewhat reduced. Each lower D scale begins at the left with a value for a pipe of 6 inch diameter.

Along its lower portion the slide has several scales visible through the window 18 and associated with the adjacent scales on the front plate to form the lower rule section. These slide scales consist of a length scale L, a drop scale H therebelow and a "parts full" scale at the left of the H scale. The lower H scale is identical with the upper H scale, and the lower L scale is similar to the upper L scale except that the former is somewhat enlarged and extends from 3000 to 20, left to right. Both L scales and both H scales are logarithmic. The low values on both of the L scales permit computations involving relatively short sewers, such as transverse sewers connecting parallel sewers laid in wide streets. The scales of the lower rule section are adjusted for a sewer running .8 full, like the scales of the upper rule section. In the lower "parts full" scale the member 1 is over the member .5, reflecting the fact that the hydraulic radius is the same for both depths of flow. Also, the number .9 is placed between the terminal number .8 and the number .7, reflecting the characteristics of the flow. The hairline 22 of the runner cooperates with the various scales of the upper and lower sections. The upper and lower rule sections are so related as to permit the conjoint use thereof, in association with the runner, for solving various problems in sewer design. Certain types of problems can also be solved by using either rule section alone. The rear frame plate has printed thereon instructions 24 for the use of the slide rule, these instructions being in the form of typical sewer design problems and their solution.

The rear face of the slide rule is also provided with standard engineer's slide rule scales A, B, CI, C, D, and K for general computation, the rear frame plate being provided with the scales A, D, and K extending along the window 19, and the slide being provided with the scales B, CI, and C. The hairline 22 of the runner 20 cooperates with these scales.

The general use of the slide rule is as follows: Assume that 100 cubic feet of sewage per second is to be discharged through a sewer 500 feet long, whose coefficient of friction is .013. If 500 on the upper L scale is set under the quantity 100 on the Q scale, the drops required for various sizes of sewers may be read on the upper H scale over the divisions on scale D_2 corresponding to the pipe diameters for N=.013. For a coefficient of friction N=.015, the rule would be set in the same manner, but the required drop would be read on the upper H scale over the divisions on scale D_1 corresponding to the pipe diameters for N=.015. The drop for other coefficients may be obtained by visual interpolation between the corresponding scale divisions of adjacent D scales, and even by extrapolation. For certain types of problems the points of interpolation may be projected to other scales of the rule by hairline 21 of the runner.

If the time of running in an established sewer is desired, the procedure is as follows: The drop on the lower H scale is set over the division corresponding to the pipe size on the lower D scale for the assumed coefficient of friction. The time of running in minutes may then be read on the T scale over the sewer length on the lower L scale. With the same setting the velocity of flow may be read on the V scale over the length on the upper L scale.

The use of the slide rule in sewer design is illustrated by the following examples:

Example 1

A sewer is to be 500 ft. long and is to discharge 14 cu. ft. per sec. The maximum amount of available fall is 2.3 ft.

(*a*) What is the necessary size and fall of the sewer if it is to run .8 full, assuming N=.013?

(*b*) What would be the velocity and time of flow?

Solution

(*a*) Using upper half of rule set 500 on "L" under 14. on "Cu. Ft. per Sec." The drop 2.3 ft. on H comes between 21'' and 24'' on the line N=.013. Therefore diameter of sewer would be 24'' and the required drop is read on the H scale over 24'', or 1.97 ft.

(*b*) Using the lower half of rule set 1.97 ft. on H over 24'' on line N=.013; then over 500 on upper L find velocity to be 5.28 ft. per sec.; and over 500 on lower L find time of flow to be 1.57 minutes on T scale.

EXAMPLE 2

(Using the data in Example 1)

(*a*) What is the necessary size and fall of the sewer if it is to run full?

(*b*) What would be the velocity and time of flow?

Solution

(*a*) Using upper half of rule set 1.0 on "Parts Full" under 14. on "Cu. Ft. per Sec." Over .8 on "Parts Full" find 13.70 cu. ft. per sec. the discharge when flowing .8 full. Now set 500 on L under 13.70 on "Cu. Ft. per Sec.," and by using runner read off the first size on line N=.013 beyond the division 2.30 on H, which gives a 24" sewer and a drop of 1.90 ft.

(*b*) Using the lower half of the rule set .8 on "Parts Full" over 24" on line N=.013; with slide in this position, move runner to 1.0 on "Parts Full," and then move slide to bring 1.90 on H under hairline of runner. Then over 500 on upper L find velocity=4.47 ft. per sec.; and over 500 on lower L find time of flow to be 1.86 minutes.

EXAMPLE 3

A sewer is to be 500 ft. long and is to discharge 14. cu. ft. per sec. The maximum amount of available fall is 2.90 ft.

(*a*) What is the necessary size of the sewer and the "Parts Full" of the sewer if the actual fall to be used is 2.90 ft. assuming N=.013?

(*b*) What would be the velocity and time of flow?

Solution

As in Example 2, find size of sewer to be 24" and necessary drop to be 1.90 ft.

(*a*) Using upper half of rule, set runner hairline on 24" on line N=.013; set 2.90 on H under hairline. Move hairline to 500 on L. Set .8 "Parts Full" under hairline. Move hairline to 14. on "Cu. Ft. per Sec." Read .68 "Parts Full" under hairline.

(*b*) Using lower half of rule, set hairline on 24" on line N=.013; set .8 "Parts Full" under hairline. Move hairline to .68 "Parts Full." Move slide so that 2.90 on H is under hairline. Then over 500 on upper L find velocity to be 6.17 ft. per sec., and over 500 on lower L find time of flow to be 1.35 minutes.

EXAMPLE 4

A 12" sewer is to be 100 ft. long and to have a drop of 1.00 ft.

(*a*) What is the discharge if it is to run full, assuming N=0.15?

(*b*) What would be the velocity and time of flow?

Solution

(*a*) Using upper half of rule, set runner hairline over 12" on line N=.015. Set 1.00 on H under hairline, and over 100 on L read 2.80 on Q. Move hairline to 2.80 on Q and set .8 on "Parts Full" under hairline. Then move hairline to 1.0 on "Parts Full" and read the discharge, 2.86 cu. ft. per sec., on Q.

(*b*) Using lower half of rule, set .8 on "Parts Full" over 12" on line N=.015. With slide in this position, move hairline to 1.0 on "Parts Full," and then move slide to bring 1.00 on H under hairline of runner. Then over 100 on upper L find velocity to be 3.60 ft. per sec. on V; and over 100 on lower L find time of flow to be 0.465 minute on T.

EXAMPLE 5

An 8" sewer is to be 100 ft. long, flowing .5 full, with a velocity of 2.70 ft. per sec.

(*a*) What is the discharge in cu. ft. per sec. and the required drop in ft., assuming N=.015?

(*b*) What is the time of flow?

Solution

(*a*) Using lower half of rule, set runner hairline over 8" on line N=.015 and set .8 on "Parts Full" under hairline. Move hairline to .5 on "Parts Full," and with runner in this position move slide so that 100 on upper L is under 2.70 on V. The required drop is read on lower H under the hairline as 1.10 ft. Over 100 on lower L, the time of flow is read on T as 0.617 minute.

(*b*) Using upper half of rule, set hairline over 8" on line N=.015. Set 1.10 on H under hairline and over 100 on L read 0.94 cu. ft. per sec. on Q for .8 full. Set hairline on 0.94 on Q, set .8 on "Parts Full" under hairline and move hairline to 0.5 on "Parts Full." Then on Q read 0.48 cu. ft. per sec.

EXAMPLE 6

A 30" sewer is to be 100 ft. long.

(*a*) What is the discharge if it is to run full, assuming N=.011?

(*b*) What is the necessary drop and velocity if the time of flow is 0.29 minute?

Solution

(*a*) Using lower half of rule, set hairline over 30" on line N=.011. Set .8 on "Parts Full" under hairline and move hairline to 1.0 on "Parts Full." With hairline in this position set 100 on L under 0.29 minute on T. Then on H read a drop of .31 ft., and over 100 on upper L read 5.75 ft. per sec. on V.

(*b*) Using upper half of rule, set hairline over 30" on line N=.011. Set 0.31 on H under hairline, and over 100 on L read 27.7 cu. ft. per sec. on Q for .8 fall. Move hairline to this discharge, and set .8 on "Parts Full" under hairline; move hairline to 1.0 on "Parts Full," and read on Q the required discharge of 28.30 cu. ft. per sec.

EXAMPLE 7

A 30" sewer has a length of 100 ft, and a drop .04 feet, and flows full at a velocity of 2.05 ft. per sec.

(*a*) What is the discharge and the value of the friction factor N?

(*b*) What is the time of flow?

Solution

(*a*) Using upper half of rule, set 100 on L under 2.05 on V, and on lower half of rule read 0.81 minute on T over 100 on L. With this setting move hairline to a drop of .04 on lower H. Set 1.0 on lower "Parts Full" under hairline; then move hairline to .8 on "Parts Full," and under hairline read 30" diameter on line N=.011.

(*b*) Using upper half of rule set hairline over 30" on line N=.011; set .04 on H under hairline, and over 100 on L read 10.00 cu. ft. per sec. on Q. Move hairline to 10.00 on Q and set .8 on "Parts Full" under hairline; then move hairline to 1.0 on "Parts Full," and on Q read the required discharge, 10.20 cu. ft. per sec.

EXAMPLE 8

An 18" sewer 100 ft. long, with a drop of 1.00 foot, discharges 0.93 cu. ft. per sec.

(*a*) What is the relative depth of flow?

(*b*) What is the velocity and time of flow?

Solution

(*a*) Using upper half of rule, set hairline over 18″ on line N=.013; under hairline set 1.0 on H, and over 100 on L read 10.10 cu. ft. per sec. on Q for .8 full. Set .8 on "Parts Full" under 10.10 on Q and move hairline to 0.93 cu. ft. per sec. on Q. Then on "Parts Full" and read 0.20 near hairline.

(*b*) Using lower half of rule, set hairline over 18″ on line N=.013. Set .8 on "Parts Full" under hairline, and then move hairline to 0.20 on "Parts Full." Set drop of 1.00 on H under hairline. Then over 100 on upper L read 3.30 ft. per sec. on V, and over 100 on lower L read 0.50 minute on T.

The foregoing examples are given to illustrate the solution of typical sewer design problems, but other related problems with different given and required elements can also be solved.

In arranging the slide rule, the logarithmic quantity of flow scale, Q, of the desired wide range of values, and the various N scales, for the desired wide range of pipe diameters, are laid out to extend over the available length of the rule. The quantity of flow is equal to the cross-sectional area of the water in the pipe (in this case for a pipe flowing .8 full) multiplied by the velocity of flow. The velocity scale, V, of the desired range, is of a convenient size to be superimposed on the quantity of flow scale, Q. The upper L, H, and "Parts Full" scales, and the various scales of the lower rule section, are then adjusted in accordance with the requirements of the Kutter formula.

The arrangement of the slide rule enables extensive scales of values to be provided in a rule of handy size and facilitates the solution of a wide variety of problems in the design of circular sewers.

What I claim as new and desire to secure by Letters Patent is:

1. A Kutter-formula sewer design slide rule for circular sewers, comprising a body member and a slide member movable with respect thereto; said rule having first and second rule sections disposed one above the other; the first rule section having on the body member a logarithmic quantity of flow scale and a logarithmic velocity of flow scale each for sewers running .8 full, and a plurality of scales of sewer diameters for different Kutter coefficients of friction; the second rule section having on the body member a logarithmic time of flow scale for sewers running .8 full and a plurality of scales of sewer diameters for different Kutter coefficients of friction corresponding to those for the first section; each of said rule sections having on the slide member a logarithmic sewer length scale, a logarithmic sewer drop scale and a "Parts Full" conversion scale.

2. A Kutter-formula sewer design slide rule for circular sewers, comprising a pair of relatively slidable first and second members; said rule having first and second rule sections disposed one above the other; the first rule section having on the first member a logarithmic quantity of flow scale and a logarithmic velocity of flow scale each for sewers running a predetermined relative depth full and a plurality of scales of sewer diameters for different Kutter coefficients of friction; the second rule section having on the first member a logarithmic time of flow scale for sewers running the predetermined depth full and a plurality of scales of sewer diameters for different Kutter coefficients of friction corresponding to those for the first rule section, each of the rule sections having on the second member a logarithmic sewer length scale, a logarithmic sewer drop scale, and a "Parts Full" conversion scale.

3. A Kutter-formula sewer design slide rule for circular sewers, comprising a pair of relatively slidable first and second members; said rule having first and second rule sections disposed one over the other; the first rule section having on the first member a logarithmic quantity of flow scale and a logarithmic velocity of flow scale each for sewers running a predetermined relative depth full and a scale of sewer diameters for a predetermined Kutter coefficient of friction; the second rule section having on the first member a logarithmic time of flow scale for sewers running the predetermined depth full and a scale of sewer diameters for the predetermined Kutter coefficient of friction; each of the rule sections having on the second member a logarithmic sewer length scale and a logarithmic sewer drop scale.

4. A Kutter-formula sewer design slide rule for circular sewers, comprising a pair of relatively slidable first and second members together forming upper and lower rule sections; the upper portion of said first member having a logarithmic quantity of flow scale and a logarithmic velocity of flow scale each for sewers running .8 full, and a plurality of scales of sewer diameters for different Kutter coefficients of friction; the lower portion of said first member having a logarithmic time of flow scale for sewers running .8 full and a plurality of scales of sewer diameters for different Kutter coefficients of friction corresponding to those for the first rule section; said slide member having as elements of the upper and lower rule sections respective sets of scales comprising a logarithmic sewer length scale, a logarithmic sewer drop scale, and a "Parts Full" conversion scale.

5. A Kutter-formula sewer design slide rule for circular sewers, comprising an elongated rule frame having a pair of parallel upper and lower windows, and a slide carried by said frame and visible at said windows; said frame and slide forming upper and lower rule sections; said frame having along one of said windows a logarithmic quantity of flow scale and a logarithmic velocity of flow scale each for sewers running .8 full, and a plurality of scales of sewer diameters for different Kutter coefficients of friction; said frame further having along the other window a logarithmic time of flow scale and a plurality of scales of sewer diameters for different Kutter coefficients of friction corresponding to those for the diameter scales along the first window; said slide having as elements for the upper and lower rule sections respective sets of scales comprising a logarithmic sewer length scale, a logarithmic sewer drop scale, and a "Parts Full" conversion scale, one set of said scales along each window.

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The following references are of record in the file of this patent:

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