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PROVISIONAL SPECIFICATION.

Improvements in Calculating Rules and the like.

I, WILLIAM JOHN GOUDIE, Engineer, of 92, Albert Drive, Crosshill, Glasgow, in the County of Lanark, do hereby declare the nature of this invention to be as follows:—

My invention relates to calculating instruments such as slide rules, and has for its object to enable the calculations required in the designing or adjusting the proportions of compound or multiple-expansion engines to be rapidly and accurately made, so that many calculations may be made on different assumptions, till the desired results be obtained.

My invention consists in an improved form of calculating rule, adapted to this purpose, and in improved arrangements and combinations of scales.

My improved calculating rule has two main parts, which may each be used separately or may be combined in one rule, each forming one face of the rule.

One of these parts I call the "synthetic," and the other I call the "analytic" part; each part is complete in itself.

The synthetic part consists essentially of a combination of scales each representing a series of values of one of the various factors from which the total indicated horse power of a multiple expansion engine can be computed, arranged and adapted to be moved relatively so that different values of the factors can be chosen at will and dealt with, and the resulting horsepower, for the chosen cylinder proportions, read off.

The analytic part of the rule consists essentially of a combination of scales, each representing a series of values of one of the indicated horsepower factors or its constituent elements, or the constituent elements of the factors of cylinder proportions, arranged and adapted to be relatively moved so that the more complex factors can be separated into their constituent elements; and by taking different values for the factors themselves the necessary elements can be determined and an analysis of the conditions made, for any chosen distribution of the total power in the various cylinders.

Constructionally the two parts of the rule are alike, the only difference being in the scales placed on each.

The synthetic part consists of a fixed rule carrying two sliders; these slide against one another, edge to edge, at the centre of the rule and are provided with suitable scales as described below. The outside edges of these sliders are provided with certain scales, and they move edge to edge with and read against suitable scales provided on the fixed parts of the rule. The analytic part of the rule is of the same construction, but its scales are different. The scales on both the synthetic and the analytic parts are partly logarithmic and partly equal division scales.

[*Price* 8*d*.]

At certain places on the rule, both on the synthetic and the analytic parts index-arrow or gauge lines are provided, and these read against the scales placed on the other parts of the rule moving in relation to the first parts, or *vice versa*.

I may, without departing from my invention, arrange and combine the scales on one or more discs or rings having motion in relation to one another and to suitable gauge points or index-arrow lines, or on one or more suitable cylinders.

In carrying my invention into effect, according to one modification I provide on the synthetic face of the rule, on the left hand part the following scales and index-arrow lines, a logarithmic scale for low pressure cylinder diametres (which can also be used for intermediate-pressure cylinder diameters); a logarithmic scale for cylinder ratios; an equal division scale for back pressures, and an index-arrow line (called hereafter "arrow E.")

On the left hand slider and along its left hand edge (sliding edge to edge with the above mentioned scales), a logarithmic scale for high pressure cylinder diametres; an index arrow line (called hereafter "arrow A,") and an equal division scale (called hereafter "scale 2.") Along the right hand edge of the slider an index arrow line (called hereafter "arrow B"); a logarithmic scale for mean pressures (called hereafter the "upper mean pressure scale"); a logarithmic scale for number of expansions (called hereafter the "lower expansion scale,") and an index arrow line (called hereafter "arrow D.")

On the right hand slider and along its left hand edge (sliding edge to edge with the scales on the right hand edge of the other slider) a logarithmic scale for cut-off in the cylinder; an index-arrow line (called hereafter "arrow G") and a logarithmic scale for initial pressures.

Along the right hand edge of the slider an index-arrow line (called hereafter "arrow C"); a logarithmic scale for piston speeds, and a logarithmic scale for mean pressures (called hereafter the "lower mean-pressure scale").

These scales slide edge to edge with the scales on the right hand fixed part, which are, a logarithmic scale for number of expansions (called hereafter the "upper expansion scale"); a logarithmic scale for indicated horse power; a logarithmic scale for diagram or efficiency factors, and an index arrow line (called hereafter "arrow F.")

I will now give a few examples of the various operations, and the modes of performing these, to illustrate some of the uses of this synthetic part of my calculating rule.

(1) To find the cylinder ratio place the high-pressure-cylinder diameter against the low pressure cylinder diameter and read the total cylinder ratio opposite "arrow A."

These two scales can be used, also, to find the ratios for the intermediate cylinders. To find the necessary diameters to give a certain chosen cylinder ratio, place the "arrow A" against the chosen ratio and any pair of diameters which come opposite one another on the high pressure and low pressure diameter scales will give the ratio required.

(2) To find the nominal number of expansions for a chosen cut off, place the "arrow A" against the cylinder ratio; place the cut off against the "arrow B," and read the number of expansions on the "upper expansion scale" opposite the "arrow C."

To find the cut off to give a certain number of expansions, place the "arrow A" against the cylinder ratio; place the "arrow C" against the number of expansions on the "upper expansion scale," and read the cut off opposite "arrow B."

(3) To find the mean effective pressure in any cylinder, or the mean effective pressure referred to the low pressure cylinder, place the "arrow D" against the initial pressure in the cylinder in question (in the case of the referred mean pressure this is the initial pressure in the high pressure cylinder) on the initial pressure scale and read result 1 on this scale opposite the number of expansions, ("lower expansion scale"); place the back pressure against this result 1 on

"scale 2" and read result 2 opposite the "arrow E"; place the "arrow F" against this result 2 on the "lower mean pressure scale," and opposite the chosen diagram factor read the mean effective pressure required.

By an inversion of this series of operations under (3), the number of expansions corresponding to any given mean pressure can be determined, and the necessary cut off then found by operation (2).

(4) To find the total indicated horsepower, place the high pressure diameter 10 against the chosen low pressure diameter; place the "arrow G" against the referred mean pressure (determined by operation (3) or otherwise) on the "upper mean pressure scale," and opposite the chosen piston speed read the indicated horse power. To find the necessary diameter of low pressure cylinder for a given horsepower (the necessary referred mean pressure having been determined from the number of expansions to be allowed) place the chosen piston speed against the indicated horse power; place the referred mean pressure (on the "upper mean pressure scale") opposite the "arrow G," and opposite the high pressure diameter 10 read the low pressure diameter required.

(5) For the case of a triple expansion engine with two low pressure cylinders, to determine the diameters of these cylinders equivalent to the single low pressure cylinder, place the high pressure diameter 14 against the single low pressure cylinder diameter and read the equivalent diameter of cylinder; for the double low-pressure cylinder engine, opposite the high pressure diameter 10.

I provide, on the analytic face of the rule, on the left hand fixed part, a logarithmic scale (called hereafter "pressure scale 7"); a logarithmic scale for diagram factors, and an index-arrow line (called hereafter "arrow H.")

On the left hand slider, and along its left-hand edge (sliding edge to edge with the above mentioned scales) a logarithmic scale (called hereafter "pressure scale 6,") and a logarithmic scale for mean pressures. Along the right hand edge of the slider an index arrow line (called hereafter "arrow L,") and an equal division scale (called hereafter pressure "scale 3.")

On the right hand slider, and along its left hand edge (sliding edge to edge with the scale on the right-hand edge of the other slider) an equal division scale (called hereafter "pressure and temperature scale 4.")

Along the right hand edge of the slider an index arrow line (called hereafter "arrow N"); a logarithmic scale for number of expansions; an index arrow line (called hereafter "arrow K,") and a logarithmic scale (called hereafter "pressure scale 5.")

These scales slide edge to edge with the scales on the right hand fixed part, which are, a logarithmic scale for initial pressures; a logarithmic scale for cylinder ratios, and an index-arrow line (called hereafter "arrow M.").

I will now give a few examples of the various operations, and the modes of performing these, to illustrate some of the uses of this analytic part of my calculating rate.

(1) From the initial pressure, the mean effective pressure, and the number of expansions in any cylinder to find the initial pressure in the next cylinder, place the suitable diagram factor against the mean effective pressure, and read result 3 opposite "arrow H"; place "arrow K" against the initial pressure and read result 4 opposite the number of expansions; place result 3 on "pressure scale 3" against result 4 on "pressure scale 4," and read the required initial pressure on "pressure scale 4" opposite "arrow L."

(2) To find the back pressure or mean back pressure in this cylinder, proceed as in operation (1) using a different value of diagram factor.

(3) From the initial pressure, the mean back pressure, and the mean effective pressure to find the number of expansions in the cylinder, place the diagram factor (suitable for back pressure in operation (2)) against the mean effective pressure, and read result 3 opposite "arrow H"; place "arrow L" against the mean back pressure on "pressure scale 4," and opposite result 3 on "pressure scale 3" read result 5 on "pressure scale 4";

place "arrow K" against the initial pressure and opposite this result 5 on the initial pressure scale read the number of expansions.

The cut off to give this number of expansions can then be determined by the synthetic part of the rule.

(4) To find the initial load on the piston determine the initial and back pressures by operations (1) and (2), then place the back pressure on "pressure scale 3" against the initial pressure on "pressure scale 4," and opposite "arrow L" on "pressure scale 4" read result 5 which is the effective initial load on the piston in pounds per square inch.

To express this as an equivalent pressure per square inch of low pressure piston area, place the ratio of this cylinder to the low pressure cylinder, against result 5 on pressure scale 5, and read the initial load, in pounds per square inch, referred to the low pressure piston, opposite "arrow M."

(5) To find the range of temperature in any cylinder place the "arrow N" against initial pressure 10; place the proper back pressure, on "pressure scale 6," against the initial pressure on "pressure scale 7," and opposite the "arrow L," on "pressure and temperature scale 4," read the range of temperature in degrees Fahrenheit.

Dated this 28th day of July 1899.

MARKS & CLERK,
18, Southampton Buildings, London, W.C.,
13, Temple Street, Birmingham, and
25, Cross Street, Manchester, Agents.

COMPLETE SPECIFICATION.

Improvements in Calculating Rules and the like.

I, WILLIAM JOHN GOUDIE, of 92, Albert Drive, Crosshill, Glasgow, Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

My invention relates to calculating instruments such as slide rules, and its object is to enable the calculations required, when designing or adjusting the proportions of multiple expansion engines, to be rapidly and accurately performed so that many calculations may be made on different assumptions till the desired results are obtained.

My invention consists in an improved form of calculating rule adapted to this purpose, and in improved arrangements and combinations of scales.

This improved calculating rule has two main parts; each part may be used separately; or the two parts may be combined in one rule, each forming one face of the rule or otherwise.

One of these parts I call the "synthetic" and the other the "analytic" part; each part is complete in itself.

The synthetic part consists essentially of a combination of scales, each representing a series of values of one of the various factors from which the total indicated horse of a multiple expansion engine can be computed (without direct reference to the particular distribution of this total power in the various cylinders), the scales being arranged and adapted to be moved relatively so that different values of the various factors can be chosen at will and dealt with, and the resulting horse power, for the chosen cylinder proportions read off; or, conversely, so that the suitable cylinder proportions for the chosen indicated horse power can be determined.

The analytic part of the rule consists essentially of a combination of scales each representing a series of values of one of the indicated horse-power factors, or its constituent elements, or the constituent elements of the factors of cylinder proportions, the scales being arranged and adapted to be relatively moved so that the more complex factors can be separated into their constituent elements; and, by taking different values for the factors themselves, the necessary elements can be determined, and an analysis of the conditions made for any chosen distribution of the total power in the various cylinders.

Constructionally the two parts of the rule are alike, the only difference being in the scales placed on each.

According to one modification of my invention the synthetic part is formed with a fixed double rule carrying two sliders: the analytic part is of the same construction but its scales are different.

The scales on both the synthetic and analytic parts are partly logarithmic and partly equal division scales.

At certain places on the rule, both on the synthetic and on the analytic part, index arrow or gauge lines are provided; and these read against the scales placed opposite and moving relatively to them. Without departing from my invention I may also arrange and combine my scales on suitable discs or rings or cylinders, the scales having motion relatively to each other and to suitable index arrow or gauge lines.

Referring now to the accompanying drawings which illustrate my invention:—

Figure 1 shows the synthetic and Figure 2 the analytic face of the rule; but I wish it to be understood that these figures are merely diagrammatic.

Referring in the first place to Figure 1, A^1 is the left hand fixed part and A^2 is the right hand fixed part of the rule, while S^1 is the left hand slider and S^2 the right hand slider.

On the fixed part A^1 are provided a logarithmic scale *a* for low pressure cylinder diameters; a logarithmic scale *b* for cylinder ratios; an equal division scale *c* for back pressures and an index arrow or gauge line B.

On the left hand edge of the slider S^1 I provide a logarithmic scale *d* for high pressure cylinder diameters, an index arrow line E, and an equal division scale *e*.

On the right hand edge of the slider S^1, I provide an index arrow line G; a logarithmic scale *f*, for mean pressures, a logarithmic scale *g* for number of expansions and an index arrow line A.

On the left hand edge of slider S^2, I provide a logarithmic scale *h*, for cut off, in the cylinder; an index arrow line D and a logarithmic scale *k* for initial pressures.

On the right hand edge of slider S^2, are situated an index arrow line F, an index arrow line K, a logarithmic scale *i* for stroke of piston, a logarithmic scale *l* for piston speed and a logarithmic scale *m* for mean pressures.

On the fixed part A^2, I provide a logarithmic scale *n* for number of expansions, a logarithmic scale *o*, for indicated horse power, a logarithmic scale *p*, for diagram or efficiency factors and an index arrow line C.

To illustrate the application of this invention to the provisional methods of designing and adjusting cylinder proportions of multiple expansion engines, I shall now describe how the principle operations and their inversions are performed, by means of the synthetic part of the rule.

1.—To determine the means effective pressure referred to the low pressure cylinder, place the index arrow line A against the initial pressure, on scale *k*, and, opposite the nominal number of expansions on scale *g*, read result 1 on scale *k*. Place this result 1 on scale *e* against the back pressure in the low pressure cylinder on scale *c*, and, opposite the index arrow line B, read result 2 on scale *e*. Place result 2 on scale *m*, against the index arrow line C, and opposite the diagram factor in scale *p*, read the referred mean pressure on scale *m*.

Similarly, if any other of these five factors is unknown, and the other four known, it can be determined by adjusting the known values in the relative positions as explained above.

2. To determine the diameter of the low pressure cylinder.

Place the piston speed, on scale *l*, against the total indicated horse power on scale *o*; place the referred mean pressure, on scale *f*, against the index arrow line D and, opposite the high pressure diameter 10, (marked with two arrow heads), on scale *d*, read the diameter of low pressure cylinder on scale *a*.

Similarly, if any other of these four factors is unknown and the three others known, the unknown factor can be determined by adjusting the slider so that the known quantities are brought into their proper relative positions, when the unknown factor will be found in its relative position opposite one of these.

For the case of a triple expansion engine with two low pressure cylinders, in order to find the diameter of each of the smaller cylinders, place the high pressure diameter 14.1 on scale *d* (marked with one arrow head) against the single low pressure diameter (as determined above) on scale *a* and, opposite the high pressure diameter 10 (marked with two arrow heads) read the diameter of the smaller cylinder on scale *a*.

3. To determine the diameter of the high pressure cylinder.

Place the index arrow line E against the total cylinder ratio, on scale *b*, and, opposite the low pressure cylinder diameter, on scale *a*, read the diameter of the high pressure cylinder on scale *d*.

Similarly, if the cylinder diameters are known, by placing their values on scales *a* and *d* against each other, their ratio can be found opposite the index arrow line E, on scale *b*.

In the same manner the diameter of the intermediate pressure cylinder or cylinders can be found from scales *b*, *a* and *d*.

4. To determine the cut off in the high pressure cylinder.

Place the index arrow line E against the total cylinder ratio, on scale *b*; place the index arrow line F against the nominal number of expansions, on scale *n* and, opposite the index arrow line G, read the cut off in the high pressure cylinder, on scale *h*.

Similarly the number of expansions can be determined by placing the known cut off on scale *h* against the index arrow line G and reading the number of expansions opposite the index arrow line F, on scale *n*.

Referring now to Figure 2, which illustrates the analytic face of the rule, B^1 is the left hand and B^2 the right hand fixed part; while T^1 and T^2 are respectively the left hand and right hand sliders.

On the fixed part B^1 are provided a logarithmic scale *q* a logarithmic scale *r*, and an index arrow line I. On the left hand edge of T^1 are located a logarithmic scale *s* and a logarithmic scale *t*;

On the right hand edge of T^1 I provide an index arrow line L and an equal division scale *u*.

On the left hand edge of T^2 is provided an equal division scale *v*.

On the right hand edge of T^2 I provide an index arrow line M, a logarithmic scale *w*, and index arrow line N and a logarithmic scale *x*.

On the fixed part B^2 are situated a logarithmic scale *y*, a logarithmic scale *z* and an index arrow line O.

To illustrate the application of this invention to an analysis of the conditions of temperature and pressure ranges in the different cylinders of multiple expansion engines, initial loads *etc.*, and to the adjustment of cut-offs to attain proper distribution of the total power in the various cylinders, I shall now described how the principal operations, to effect these objects, are performed by means of the analytic part of the rule.

1. To find the back pressure in any cylinder, place a suitable diagram factor, or scale *r*, against the mean effective pressure in the cylinder, on scale *t*, and read result 1 opposite the index arrow line I, on scale *t*.

Place index arrow line N against the intial pressure on scale *y*; and, opposite the number of expansions on scale *w*, read result 2 on scale *y*. Place result 1, on scale *u* against result 2 on scale *v* and read the back pressure, opposite index arrow line L, on scale *v*.

2. To find the initial pressure in the next cylinder, proceed as in operation 1, using a different value of diagram factor.

3. To find the number of expansions in the cylinder. Place the suitable diagram factor, on scale *r*, against the mean effective pressure, on scale *t*, and opposite the index arrow line I read result 1 on scale *t*. Place index arrow line L against the back pressure, on scale *v*, and, opposite result 1 on scale *u*, read result 2 on scale *v*. Place the index arrow line N against the initial pressure, on scale *y*, and, opposite result 2 on scale *y*, read the number of expansions on scale *w*.

4. To find the initial load on the piston, and reduce it to equivalent load on the low pressure piston. Determine the back pressure and initial pressure by operations 1 and 2; then place the back pressure on scale *u*, against the initial pressure on scale *v*; and, opposite the index arrow line L, read result 1, on scale *v*. This is the effective initial load on the piston.

Next place the ratio of this cylinder to the low pressure cylinder, on scale *z*, against result 1, on scale *x*; and read the initial load referred to the low pressure piston opposite index arrow line O on scale *x*.

5. To find the range of temperature in any cylinder. Place the index arrow line M against the initial pressure 10 on scale *y* (marked with one arrow head), place the back pressure on scale *s*, against the initial pressure, on scale *q*; and, opposite the index arrow line L, read the range of temperature in degrees Fahrenheit on scale *v*.

By means of the synthetic part of my rule the following series of calculations and inversions of these, involved in the provisional design and adjustment of cylinder proportions for multiple expansion engines, can be rapidly made without reference to tables and without the performance of arithmetical work, a valuable saving of time and labour being effected:—

The determination of the referred mean pressure from the initial pressure, number of expansions, back pressure, and diagram or efficiency factor.

The determination of the diameter of the low pressure cylinder from the referred mean pressure, piston speed, and total indicated horse power.

In the case of a triple expansion engine with two low pressure cylinders, the determination of the diameter of each of the low pressure cylinders from the single low pressure diameter.

The determination of the diameter of the high pressure cylinder from the low pressure diameter and the cylinder ratio.

The determination of the diameter of intermediate cylinders of triple and quadruple expansion engines from the cylinder ratios and diameters of the high pressure and low pressure cylinders.

The determination of the cut off in the high pressure cylinder from the number of expansions and the total cylinder ratio.

By means of the analytic part of my rule, the following series of analytic operations connected with the power distribution in multiple expansion engines can be rapidly accomplished without reference to tables or the performance of any arithmetical work, thus saving much time and labour:—

The determination of the back pressure in any cylinder from the initial pressure, mean effective pressure number of expansions and diagram factor.

The determination of the initial pressure in the next succeeding cylinder, from the mean effective pressure, initial pressure, number of expansions and suitable diagram factor.

The determination of the number of expansions, for adjustment of cut off, from the initial pressure, back pressure mean effective pressure and suitable diagram factor.

The determination of the initial load on the piston of any cylinder from the initial and back pressures and the further determination of its equivalent load on the low pressure piston from the cylinder ratio.

The determination of the range of temperature in any cylinder from the initial and back pressures.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1.—A calculating rule consisting of a fixed portion and sliders or of two or more discs or rings or cylinders movable relatively to each other, provided with the combination of scales and index arrow lines substantially as and for the purposes hereinbefore described with reference to Figure 1.

2.—A calculating rule comprising essentially a combination of scales each representing a series of values of one of the various factors from which the total indicated horse power of a multiple expansion engine can be computed (without direct reference to the particular distribution of this total power in the various cylinders), the scales being arranged and adapted to be moved relatively so that different values of the various factors can be chosen at will and dealt with, and the resulting horse power, for the chosen cylinder proportions, read off; or, conversely, so that the suitable cylinder proportions for the chosen indicated horse power can be determined, substantially as described with reference to Figure 1.

3.—A calculating rule comprising three pairs of relatively moving parts: the first pair having on one of its parts a logarithmic scale such as *a*, a logarithmic scale such as *b*, an equal division scale such as *c* and an index arrow line such as B, and on its other part a logarithmic scale such as *d*, an index arrow line such as E and an equal division scale such as *e*; the second pair having on one of its parts an index arrow line such as G, a logarithmic scale such as *f*, a logarithmic scale such as *g* and an index arrow line such as A, and on its other part a logarithmic scale such as *h*, an index arrow line such as D and a logarithmic scale such as *k*; and the third pair having on one of its parts an index arrow line such as F, an index arrow line such as K, a logarithmic scale such as *i*, a logarithmic scale such as *l* and a logarithmic scale such as *m*, and on its other part a logarithmic scale such as *n*, a logarithmic scale such as *o*, a logarithmic scale such as *p* and an index arrow line such as C; substantially as and for the purpose described with reference to Figure 1.

4.—A calculating rule consisting of a fixed portion and sliders, or of two or more discs or rings or cylinders movable relatively to each other, provided with the combination of scales and index arrow lines, substantially as and for the purposes hereinbefore described with reference to Figure 2.

5.—A calculating rule comprising essentially a combination of scales each representing a series of values of one of the indicated horse-power factors, or its constituent elements, or the constituent elements of the factors of cylinder proportions, the scales being arranged and adapted to be relatively moved so that the more complex factors can be separated into their constituent elements; and, by taking different values for the factors themselves, the necessary elements can be determined, and an analysis of the conditions made for any chosen distribution of the total power in the various cylinders, substantially as described with reference to Figure 2.

6.—A calculating rule comprising three pairs of relatively moving parts; the first having on one of its parts a logarithmic scale such as *q*, a logarithmic scale such as *r* and an index arrow line such as I, and on its other part a logarithmic scale such as *s* and a logarithmic scale such as *t*; the second pair having on one of its parts an index arrow line such as L and an equal division scale such as *u*, and on its other part an equal division scale such as *v*; and the third pair having on one of its parts an index arrow line such as M, a logarithmic scale such as *w*, an index arrow line such as N and a logarithmic scale such as *x*, and on its other part a logarithmic scale such as *y*, a logarithmic scale such as *z* and an index arrow line such as O; substantially as and for the purposes described with reference to Figure 2.

Dated this 26th day of April 1900.

MARKS & CLERK,
18, Southampton Buildings, London, W.C.,
13, Temple Street, Birmingham, and
25, Cross Street, Manchester, Agents.

Redhill: Printed for Her Majesty's Stationery Office, by Malcomson & Co., Ltd.—1900.

Fig. 1.

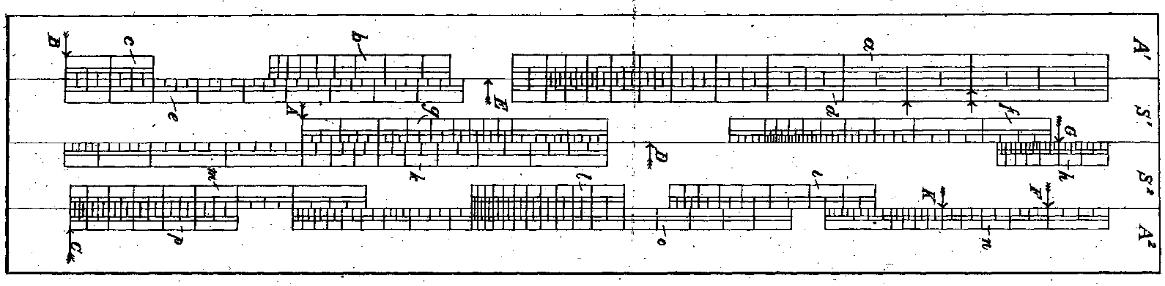

Fig. 2.

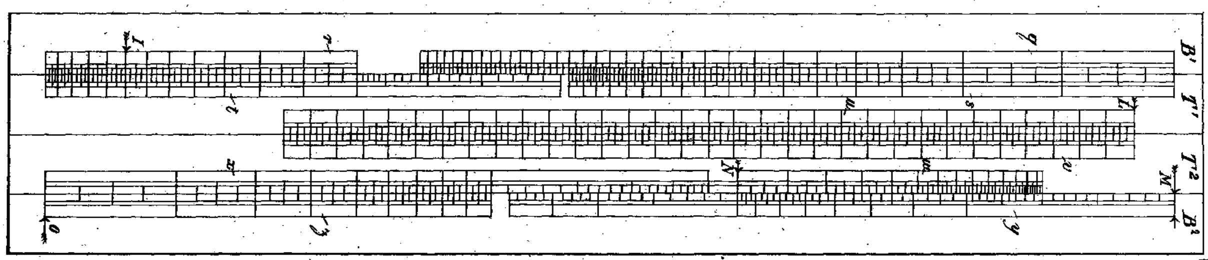

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Fig. 1.

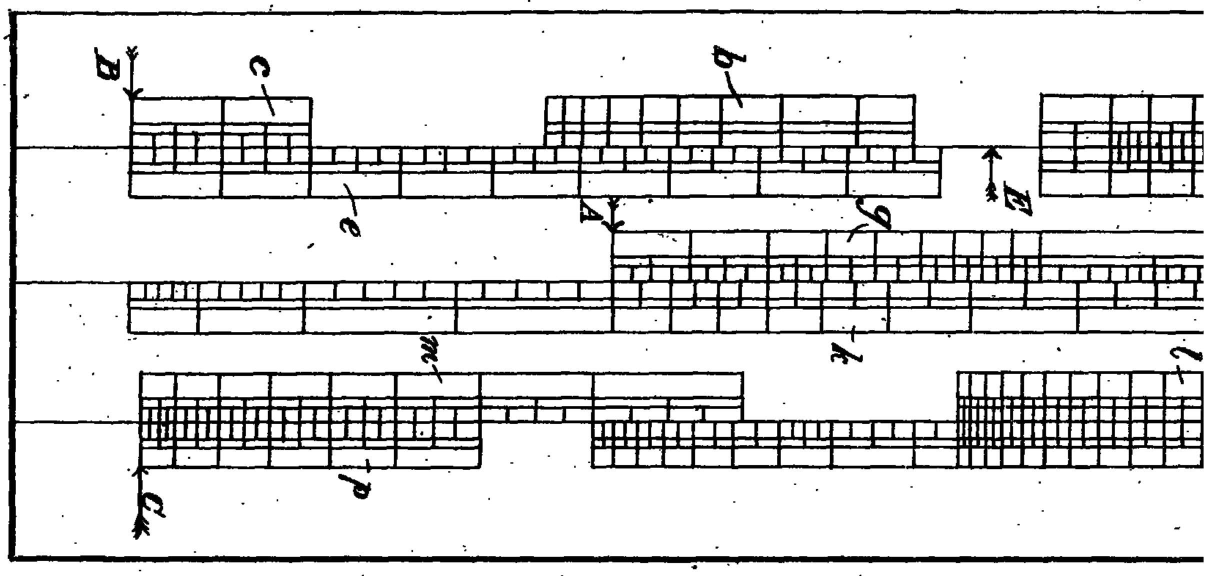
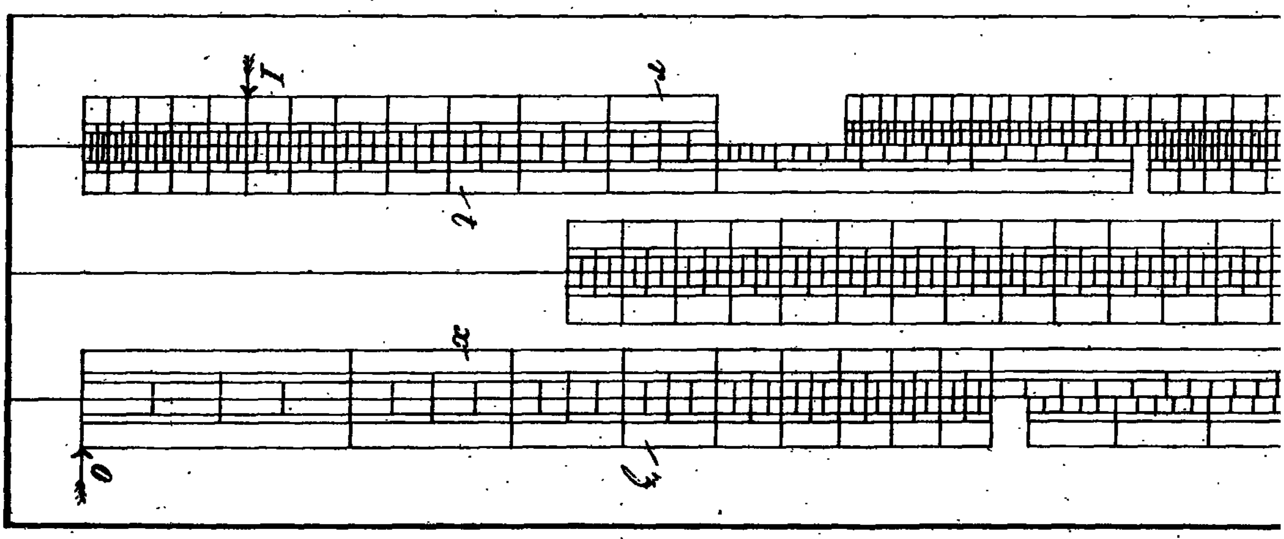


Fig. 2.



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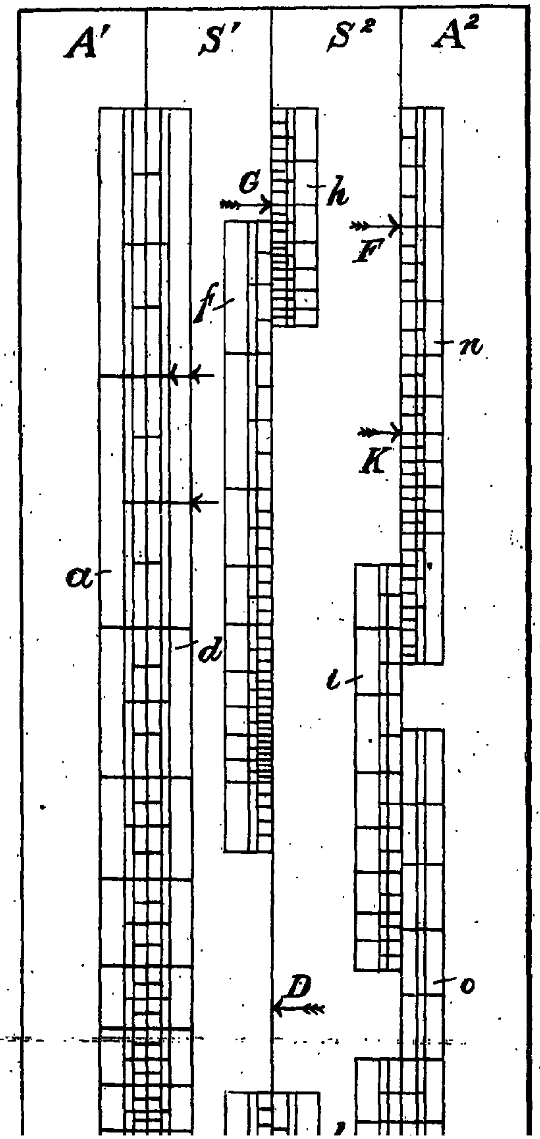

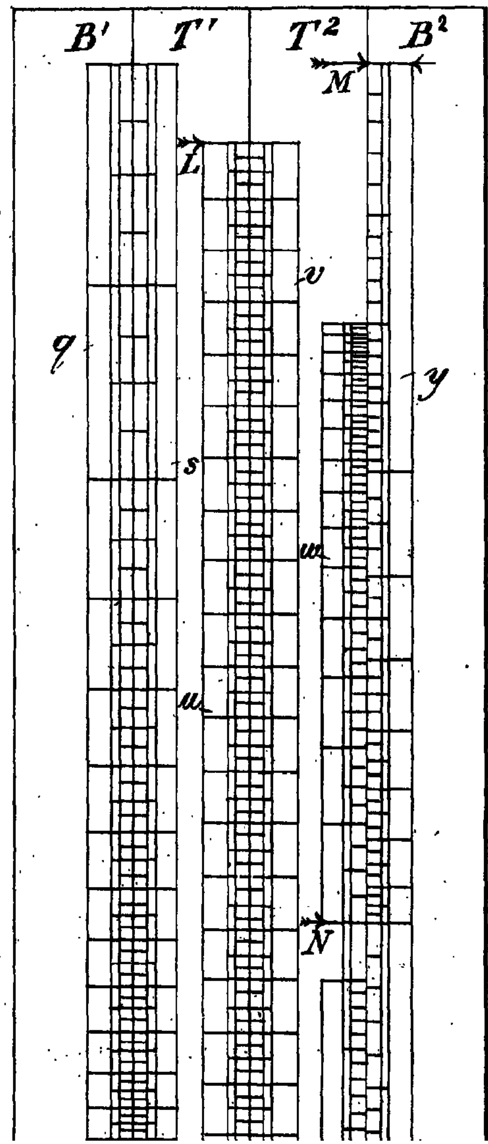

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