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PROVISIONAL SPECIFICATION.

Improvements in Power Computing Slide Rules for Steam and other Engines.

I, HENRY ALBERT GOLDING, of 51 The Grove, Wandsworth Common, London, S.W. Mechanical Engineer do hereby declare the nature of this invention to be as follows:—

My invention relates to special forms of slide rules or calculating instruments, whereby various formula relating to the computation of the horse power of steam and other engines may be solved automatically by means of sliding one or more scales alongside of other scales, and so obtain the required result mechanically.

I so arrange the slides and scales that various forms of the instrument or apparatus may be used to obtain different results. In one form, the horse-power computing scale for steam engines, shewn in Figures I and II of the accompanying drawing, I arrange the stock or fixed portion of the rule, 1, either in the flat form or circular, suitably grooved as shewn in Fig: I, to take or receive three separate sliders marked 2, 3, and 4, each of which can be moved or rotated within the stock separately and independently of each other. The upper or outer surfaces of the stock 1, and the sliders 2, 3, and 4, I engrave, mark, or graduate with suitable logarithmic scales, each representing one of the various quantities involved in determining the horse power of any steam engine, as shewn in Fig: II. For example, the lower portion of the stock 1, I engrave with a logarithmic scale 5, representing various boiler pressures from 10 to 500 lbs per square inch, and the upper portion of the stock is engraved or marked with a logarithmic scale 6 representing horse power; both of these scales and other scales mentioned in this specification being unlimited in extent, but for convenience of illustration, the scales are shewn drawn to a base of 125 millimetres. Of the three sliders mentioned, 4, 3, and 2, the former is graduated on its lower edge with a scale representing various ratios of expansion; and on its upper edge with a small auxiliary scale representing various diagram factors, and a gauge point G. P. for indicating the stroke. On the upper or outer surface of the central slider 3, I arrange two scales, one at the lower edge representing the stroke of the engine in feet and inches; and one on the upper edge representing the diameter of the cylinder, or in the case of multi-cylinder engines, the diameter of the largest or low pressure cylinder, also in feet and inches. As the horse power of the engine varies with the square of the diameter of the cylinder or cylinders, I arrange that the scale representing it shall have a base twice as long as the other scales, namely 250 millimetres. The third slider, 2, has on its lower edge a scale representing the speed of the engine in revolutions per minute, and on its upper edge two short scales representing the mechanical efficiencies of single-acting and double-acting engines respectively. The upper portion of the stock is provided with the logarithmic scale of horse power 6, already referred to, drawn to the same base as scale 5.

Although for the purposes of illustration, this rule and others subsequently described and illustrated, are graduated in feet and inches, and lbs. per square inch pressure, and other units of English measurement, yet I claim for such

[Price 8d.]



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rules or instruments that they may be graduated in metric or any foreign system of measurement for similar purposes.

The method of using my apparatus is as follows. Where the size, pressure, and speed of any engine are known, to find the probable brake or indicated horse power developed, set the given number of expansions on slider 4, against the known boiler pressure on scale 5, and the index point x will denote the theoretical mean pressure on the lower scale of slider 3. Subtract from this the back pressure (say 3 lbs. for condensing engines and 16 or 18 lbs. for non-condensing engines), and set a suitable diagram factor against the difference, when the estimated mean effective pressure will be indicated by x . Now move the slider 3 until the given stroke comes opposite the gauge point G. P., and set the revolutions on slider 2 against the given size of cylinder (or low pressure cylinder in the case of more than one), when the indicated horse power will be found on scale 6 on the upper portion of the stock, and the brake horse power for any given mechanical efficiency for either a single-acting or a double-acting engine as the case may be.

If the power and size of cylinder be given, and it is required to find the necessary boiler pressure to develop the given power, the reverse of these operations are gone through. If the power and pressure be known, and it is required to find the size of cylinder or speed necessary to develop the given power, the various sliders are moved to the quantities known, and the remaining function found by manipulation. The rule or apparatus is thus so arranged that the required result can be found without the aid of any calculation whatever; and moreover, the result of varying any one or more of the factors determining the result, such as pressure, expansions, diameter, stroke or speed may be seen at a glance.

When the actual mean effective pressure is known or given instead of the boiler pressure, the operation of finding the power can be shortened by bringing the mark representing 1 expansion on the bottom of slider 4 to the known mean effective pressure as represented on the boiler-pressure-scale 5, and setting the stroke to gauge point G. P. as before described. In the case of multi-cylinder engines, the diameters of the smaller cylinders may be found by bringing the index 10 on slider 2 against the diameter of the largest cylinder, and the diameters of the smaller cylinders will be indicated on the scale at the top of slider 3 opposite the given ratios of cylinder areas.

For the purpose of adapting my apparatus to determine the power of any internal combustion motor using an explosive mixture of gas, oil, petrol, spirit, or other gasoline with air, I employ a rule with two loose sliders only, such as that shewn in Figs: III & IV. In this form of rule or instrument I engrave a scale or scales 7 on the bottom of the stock or fixed portion of the rule, representing the diameter of the cylinder or cylinders of such motor, either in inches, millimetres, or any other suitable unit of measurement, and on the lower portion of the lower slider I engrave a corresponding scale or scales 8 to one half the base of scales 7, representing the length of the stroke of the piston or pistons of the motor. On the upper edge of the lower slider is placed a scale of revolutions per minute; and on the lower edge of the upper slider a scale representing the number of cylinders employed, and on its upper edge two short scales 9 and 10 representing the power of the motor according to the cycle of operations adopted; the former scale 9 shewing the horse power for a four-cycle motor or one in which an explosion occurs in each cylinder at every fourth stroke of the piston or pistons, and the latter scale 10 representing the proportionate increase of power by adopting the two-cycle system in which an explosion is obtained for every two strokes of the piston. The top of the stock or immovable portion of the rule is engraved with a logarithmic scale 11 representing horse power, which for convenience of illustration is shewn drawn to a base of 125 millimetres.

The method of using this form of my apparatus is as follows. Where the

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size and speed are known, to find the horse power, set the stroke on scale 8 to the diameter on scale 7, (using either metric or English units as desired) and opposite the speed set the number of cylinders, when the indicators 9 and 10 will point to the required power according to the cycle employed. If the power be given, and it is required to find the size of cylinder necessary, the reverse of these operations are gone through. Similarly if the sizes of the cylinders are known, and the power, the speed can be found by setting the stroke on scale 8 to the given diameter on scale 7, and the upper slider to the known power (using either indicator 9 or 10 according to the cycle employed), when the speed will be denoted under the number of cylinders employed.

As the power of internal combustion engines varies slightly according to the amount of compression used, I provide two subsidiary scales 9 and 10 to the power indicators, representing some 20 *per cent* above and below the mean, so that when the correct percentage is found for any given motor, the same can be used for other motors of similar design working with similar amounts of compression.

For the purpose of finding the brake horse-power of any engine I employ a rule shewn in Figs V and VI, with only a single slider 12 on which are two graduated scales 13 and 14, the former representing the speed in revolutions per minute, and the latter the nett weight or pull on the brake rope in lbs or kilogrammes as the case may be. The base of the stock is graduated with two logarithmic scales 15 representing the effective diameter of the brake wheel, pulley, or drum, in both English and metric measurements, whereas the top of the stock is provided with a logarithmic scale representing the brake horse-power developed, all the scales being drawn for convenience of illustration, to a base of 125 millimetres.

The method of using this form of the rule is very similar to that adopted with the other forms already described. With a given size of brake wheel or pulley, and at a known speed and brake load, to find the brake power absorbed, set the nett weight or pull on scale 14 to the size of brake pulley on scale 15, and opposite the revolutions shewn on scale 13 the power is indicated on the scale at the top of the rule. Similarly for a given power, to find the requisite load to be carried at any given speed, set the speed on scale 13 to the given power; and opposite the known size of wheel on scale 15 read off the corresponding load on scale 14. Similarly to find the required speed at which the motor must run and carry a known load to develop a given power, set the load on scale 14 to the diameter of brake wheel on scale 15; and underneath the given power, read off the requisite speed on scale 13.

I am aware that the ordinary form of slide rule with a single slide can be used for obtaining the various results of the operations herein described, but they do not give the result directly, except by the aid of laborious calculation, and the introduction of physical constants which the use of my form of rule dispenses with.

Dated this 8th day of April, 1907.

HENRY A GOLDING,
Applicant.

COMPLETE SPECIFICATION.

Improvements in Power Computing Slide Rules for Steam and other Engines.

I, HENRY ALBERT GOLDING, of 51 The Grove, Wandsworth Common, London, S.W. Mechanical Engineer do hereby declare the nature of this invention and

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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 special forms of slide rules or calculating instruments, whereby various formulae relating to the calculation of the horse power of steam, gas, or oil engines, petrol and other motors, may be solved automatically by means of sliding one or more scales alongside of other scales, and so obtain the required result mechanically.

I so arrange the scales and slides that various forms of the instrument or apparatus may be used to obtain different results. In one case, the horse-power computing scale for steam engines, shewn in Figs. I and II of the drawing left with the Provisional Specification, I arrange the stock or fixed portion of the rule 1 either in the flat form or cylindrical, suitably grooved to take three separate sliders or cylinders 2, 3 and 4, shewn in Figs. I and II, each of which can be moved or rotated within the stock separately and independently of each other, the upper or outer edges of the stock 1 and the sliders 2, 3 and 4 being engraved, marked, or graduated with suitable logarithmic scales representing the various quantities involved in determining the horse-power or size of any steam engine as shewn in Fig II. For example, the lower portion of stock 1, I engrave with a logarithmic scale 5 representing various boiler pressures from 10 to 500 lbs. per square inch; and the upper portion of the stock is engraved or marked with a logarithmic scale 6 representing horse-power; both of these scales and other scales mentioned in this specification being unlimited in extent, the same principle applying to greater or less powers as required. Of the three sliders, 4, 3 and 2, the former is graduated on its lower edge with a scale representing various ratios of expansion, and on its upper edge it has a small auxiliary scale representing diagram factors, and a gauge point G. P. for indicating the stroke. On the upper or outer surface of slider 3, I arrange two scales, the one on the lower edge at the left hand side representing the stroke of the engine in feet and inches, and that on the right hand side the mean effective pressure obtained in the cylinder or cylinders of the engine. On the upper edge of this slider 3, I arrange a scale representing the diameter of the cylinder in inches; or, in the case of multi-cylinder engines, the diameter of the largest or low-pressure cylinder. As the horse-power of the engine varies with the square of the diameter of its cylinder or cylinders, I arrange that the scale representing the diameter shall have a base twice as long as the other scales mentioned, being drawn to a base of 25 centimetres for convenience, whereas the other logarithmic scales have a base of $12\frac{1}{2}$ centimetres. The remaining slider 2 has on its lower edge a logarithmic scale representing the speed of the engine in revolutions per minute, and on its upper edge two short scales representing the mechanical efficiencies of single-acting and double-acting engines respectively. The upper portion of the stock is provided with the logarithmic scale 6 representing horse-power as already described.

With a size of rule similar to that referred to, the distances from the extreme left hand edges of the stock 1 and sliders 2, 3 and 4, Figures I and II, to each of the gauge points, and the commencement of each of the scales, are as follows. The distance from the extreme left hand edge of the stock to the first graduation of 10 lbs. on the boiler pressure scale 5, Figure II is 50 millimetres. The distance from the extreme left hand edge of slider 4 to the graduation 1 on the ratio of expansion scale is 138 millimetres; whilst the distance from the same edge of the same slider to the gauge point G. P. is 74 millimetres, and the distance from the same edge of the same slider to the index point x of the scale for diagram factors is 233 millimetres. On the centre slider 3, Figure II, the distance from the extreme left hand edge of the slider to the graduation 10 feet on the stroke scale is 7 millimetres, the distance from the same edge of the same slider to the graduation 10 lbs. on the mean effective pressure scale is 144 millimetres, and from the same edge of the

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same slider to the graduation 6 inch on the scale for diameters of cylinders is 12 millimetres. On the remaining slider 2 Figure II, the distance from the extreme left hand edge of the slider to the graduation 1000 on the revolutions scale is 13 millimetres, and the distances from the same edge of the same slider to the two graduations 1.0 on the mechanical efficiency scales are 151 millimetres and 188 millimetres for single-acting and double-acting engines respectively. The distance from the extreme left hand edge of the stock 1 Figure II to the graduation 10 on the horse-power scale 6 is 13 millimetres. For other sizes of rule with the logarithmic scales constructed to a different base to that referred to, namely $12\frac{1}{2}$ centimetres, these distances are increased or decreased proportionately.

All the scales on this form of my rule and other forms about to be described are purely logarithmic scales in which the various graduations are engraved, marked, or printed upon scales at definite distances from each other, such distances being proportional to the difference in the logarithms of the numbers they represent; with the exception of one scale only, the scale for ratios of expansion shewn at the bottom of slider 4 Figure II. This scale is plotted proportionally to the constant c , where c represents the ratio that the mean effective pressure bears to the initial pressure in the case of steam expanded hyperbolically. The value of this constant c for various ratios of expansion r can be calculated from the formula:—

$$c = \frac{1 + \log_e r}{r}$$

r , being the ratio of expansion required; or its value can be found from any table of these constants to be found in any text book on steam and the steam engine.

Although for the purpose of illustration, this form of my rule, and other forms subsequently described and illustrated, are graduated by scales representing feet, inches, lbs. per square inch pressure, and other units of English measurement, yet I claim for all the forms of my rule that it may be graduated in metric or any other foreign system of measurement for similar purposes.

The method of using this form of my apparatus is as follows:—

Where the size, boiler pressure and speed of any steam engine is known, to find the probable brake or indicated horse-power developed, set the given ratio of expansion against the boiler pressure indicated on scale 5, and the index point x will record the theoretical mean effective pressure on the lower scale of slider 3. Subtract from this a suitable back pressure, and set the given diagram factor against the difference, when the estimated actual mean effective pressure will be indicated by x . Now move the slider 3 until the given stroke comes opposite the gauge point G. P.; and set the revolutions on slider 2 against the given size of cylinder, when the indicated horse-power will be given direct on scale 6, and the brake horse-power for any given mechanical efficiency, either single or double acting as the case may be.

If the power and size of cylinder be given, and it is required to find the necessary pressure of steam, the reverse of these operations is gone through. If the power and pressure be known, and it is required to find the size of cylinder or speed necessary to develop the given power, the sliders are moved or rotated to the known quantities, and the remaining function found by manipulation. This form of my rule is thus so arranged that the required result may be found without the aid of any calculation whatever; and moreover, the effect of varying any one or more of the factors governing the result, such as pressure, expansions, stroke, diameter or speed, may be seen at a glance.

In another form of my apparatus for determining the power of any internal combustion motor, using an explosive mixture of gas, oil, or petrol with air, I employ a slightly different form of rule with two sliders, such as that shewn

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in Figs. III & IV. In this form of rule I engrave a scale or scales 7 on the bottom of the stock or fixed portion of the rule representing the diameter of the cylinder or cylinders of such motor, either in inches, millimetres, or any similar foreign system of measurement, and on the lower portion of the lower slider I engrave a corresponding scale or scales 8 representing to one-half the base of the diameter scale, the length of the stroke of such motor. On the upper edge of the lower slider is placed a scale of revolutions per minute, and on the lower edge of the upper slider a scale representing the number of cylinders employed; and on its upper edge two short scales 9 and 10 representing the power of the motor according to the cycle of operations adopted; the former scale 9 shewing the horse-power for a four cycle motor or one in which an explosion occurs in each cylinder at every fourth stroke of the piston or pistons, and the latter scale 10 shewing the horse-power for a motor on the two-cycle principle, or one in which an explosion occurs at every second stroke of the piston. The top of the stock or immovable portion of the rule is graduated with a logarithmic scale to the normal length of base of $12\frac{1}{2}$ centimetres representing the horse-power developed.

The method of using this form of my rule is as follows:—Where the size and speed are known, to find the horse-power, set the stroke on scale 8 to the diameter on scale 7 (using either metric or English units as desired), and opposite the speed set the number of cylinders, when the indicators 9 and 10 will point to the required power according to the cycle employed. If the power be given, and it is desired to find the size of cylinder, the reverse of these operations is gone through. Similarly if sizes are given and the power, the speed can be found by setting the stroke on scale 8 to the given diameter, and the upper slider to the power, (using either indicator 9 or 10 according to the cycle employed), when the required speed will be found opposite the number of cylinders employed.

The distances from the extreme left hand edge of the stock and sliders for this form of my rule for a size of rule similar to that shewn in Figure III, to each of the various scales and index points, are as follows. For the scales 7 at the bottom of the stock, the distance to the graduation 70 representing a cylinder or cylinders of 70 millimetres diameter, the distance is 15 millimetres; and the distance from the same point to the graduation 3 inches is 140 millimetres. For the two scales 8 at the bottom edge of the lower slider, the distance to the graduation 300 millimetres, representing a cylinder or cylinders of 300 millimetres stroke, is 20 millimetres; and the distance to the graduation 10 inches on the corresponding right-hand scale is 145 millimetres. For the scale of revolutions on the top of the same slider, the distance to the graduation 300 is 71 millimetres. For the scale at the bottom of the top or upper slider representing the number of cylinders used, the distance to the graduation 16 is 20 millimetres; and on the same slider for scale 9, the distance to the index point marked 1.0 is 123 millimetres. For scale 10 the distance to the corresponding index point marked 1.0 for two-cycle motors is 151 millimetres. For the scale 11, at the top of the stock, the distance to the graduation 2 is 15 millimetres. All the above scales are purely logarithmic, and are all drawn to a base of $12\frac{1}{2}$ centimetres for convenience of illustration, except the two scales 7 which are drawn to a base of 25 centimetres.

As the power varies slightly according to the amount of compression used, I provide the two additional subsidiary scales 9 and 10 to the power indicators, representing some 20 per cent below and above the mean, so that when the correct percentage is found for any given motor, the same can be used for other motors of similar design working with an equal amount of compression.

In another form of my rule to represent the brake horse-power shewn in Figs V and VI, I use only a single slider 12 on which are two graduated logarithmic scales 13 and 14; the former representing the speed in revolutions per minute, and the latter the nett load on the brake in lbs. or kilogrammes.

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The base of the stock is graduated with two logarithmic scales, 15, right and left respectively, representing the diameter of the wheel in inches, and the diameter in centimetres, whereas the top of the stock is graduated to represent the brake horse-power developed.

- 5 The method of using this form of my rule is very similar to that already explained. With a given size of brake wheel or pulley, and at a given speed and brake load, to find the power, set the nett brake load on scale 14 to the diameter of the wheel on 15, and opposite the revolutions shewn on scale 13, the power is given on the scale at the top of the rule. Similarly for a given
10 power to find the requisite load to be carried at any given speed; set the speed on scale 13 to the power, and opposite the diameter of the wheel on scale 15, read off the corresponding load on scale 14. Similarly to find the required speed at which the motor must run and carry a given load to develop a given power, set the load on scale 14 to the size of brake wheel on scale 15,
15 and opposite the given power read off the requisite speed on scale 13.

- The distances from the extreme left hand edges of the stock and slider for this form of my rule, for the size of rule shewn in Figure V to each of the various scales, are as follows. For the scale 15 left at the bottom of the stock, the distance to the graduation 10 centimetres, is 23 millimetres, and the
20 distance to the graduation 6 inches on the corresponding scale 15 right, measured from the extreme left hand edge of the stock, is 162 millimetres. For the scales 14 at the bottom of the slider, the distance to the graduation 300 kilogrammes on the left hand scale is 35 millimetres, and the distance to the graduation 500 lbs on the corresponding right-hand scale is 165 millimetres.
25 For the scale 13 at the top of the slider, the distance to the graduation 200 revolutions is 16 millimetres, and for the scale at the top of the stock representing the brake horse power, the distance to the graduation 5 is 15 millimetres. All of the scales in this form of my rule are purely logarithmic scales, drawn to a base of $12\frac{1}{2}$ centimetres.

- 30 It will be obvious from an inspection of the drawings that the exact position or locality of each scale has no material effect upon the rule; for example, in the last form shewn in Figs. V and VI, the scales 15 representing the diameter of the brake wheel may be placed at the top of the rule if desired, and the horse-power scale graduated on the bottom of the rule.

- 35 I am aware that special forms of slide rules have been used for calculating the power of steam engines before, but to these I lay no claim.

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:—

- 40 (1) A three-slide rule giving the power of all sizes of steam engines for any given boiler pressure such as that described and illustrated in Figs. I and II.
(2) A double-slide rule for determining the power of internal combustion motors of one or more cylinders using explosive mixtures of spirit or gas, such as that described and illustrated in Figs. III and IV.
45 (3) A single-slide rule for finding the brake-horse-power of any motor or engine such as that described and illustrated in Figs V and VI.

Dated this Eighth day of October 1907.

HENRY ALBERT GOLDING.
Applicant.

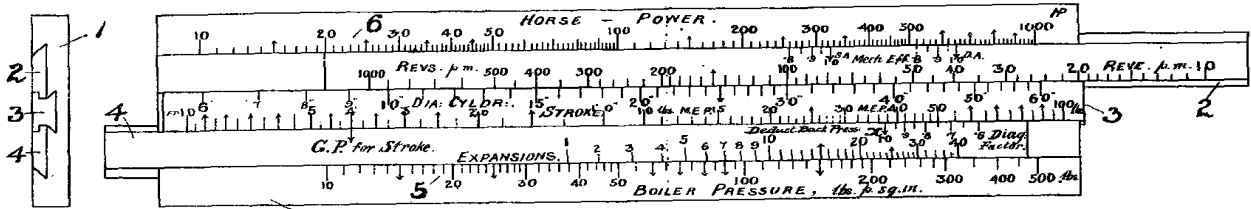


FIG. I

FIG. II

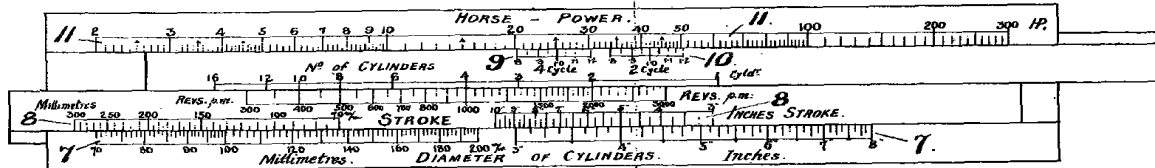


FIG. III

FIG. IV

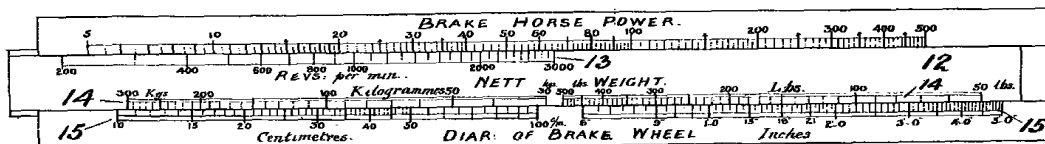
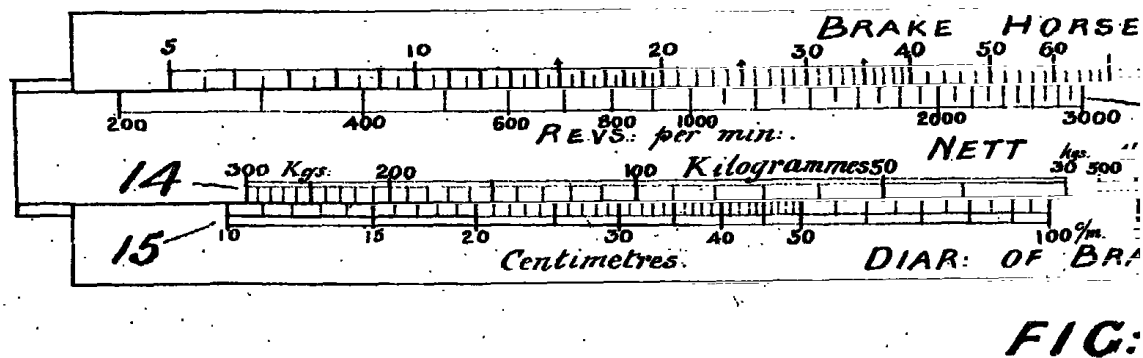
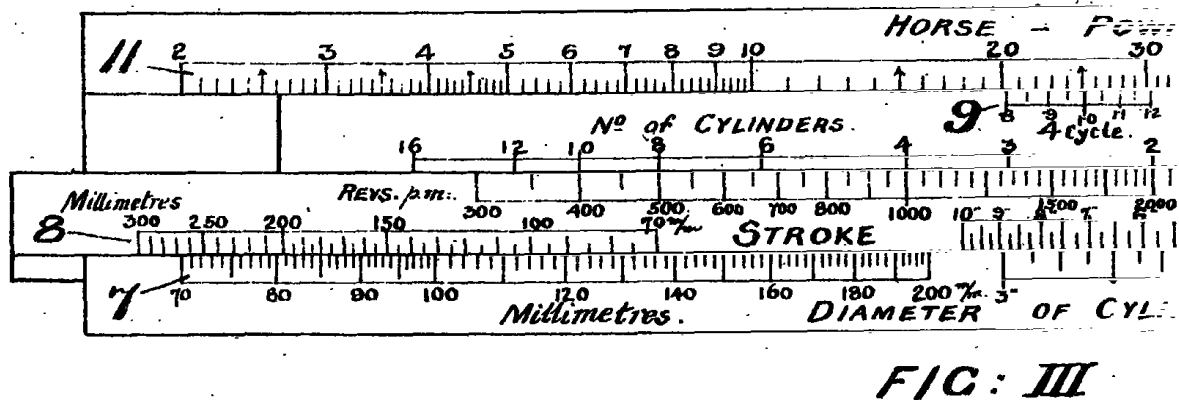
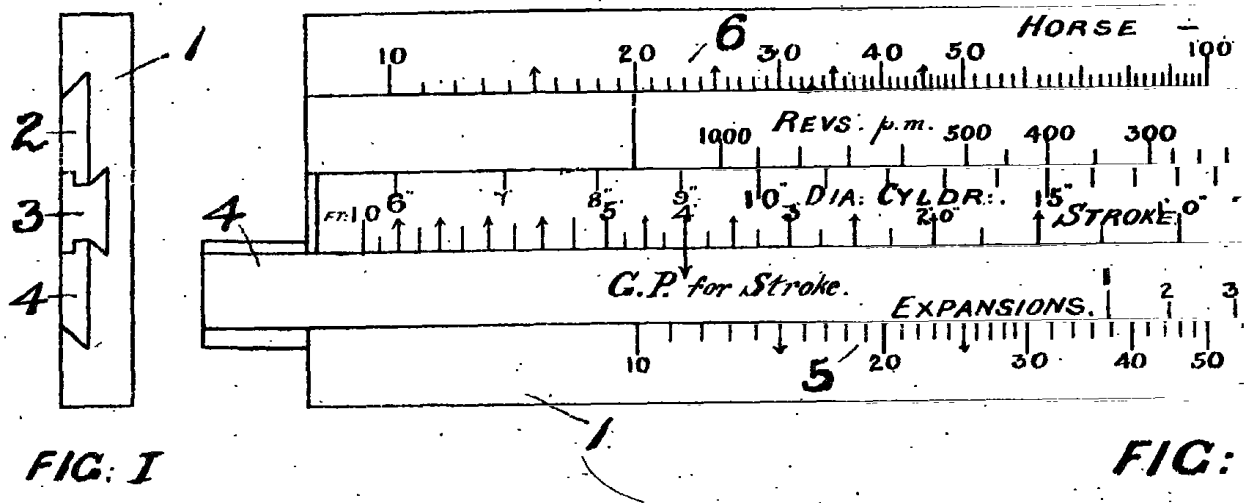


FIG. V

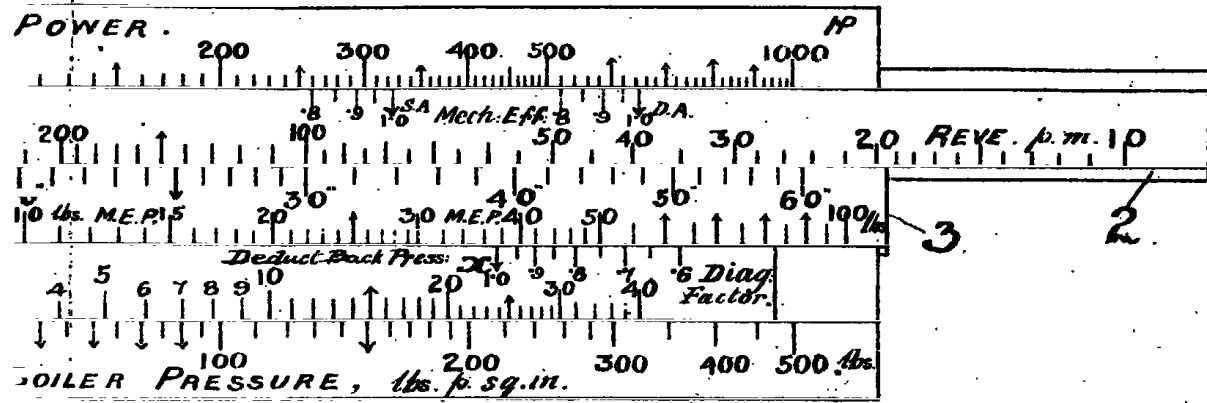
FIG. VI



[This Drawing is a reproduction of the Original on a reduced scale.]



[This Drawing is a reproduction of the Original on a reduced scale.]



II.

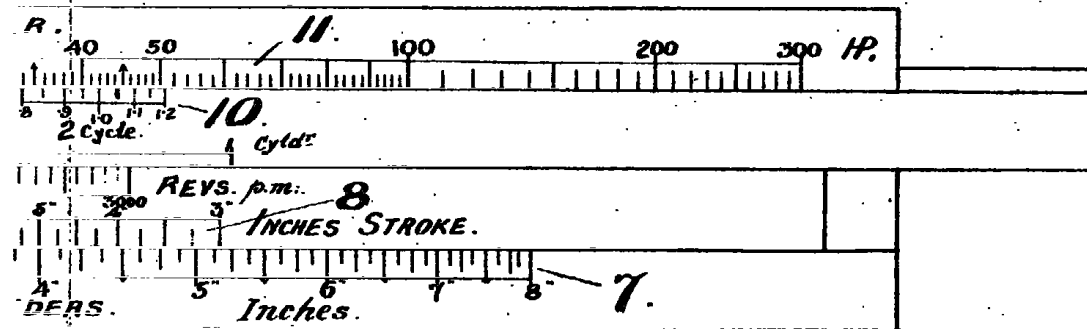
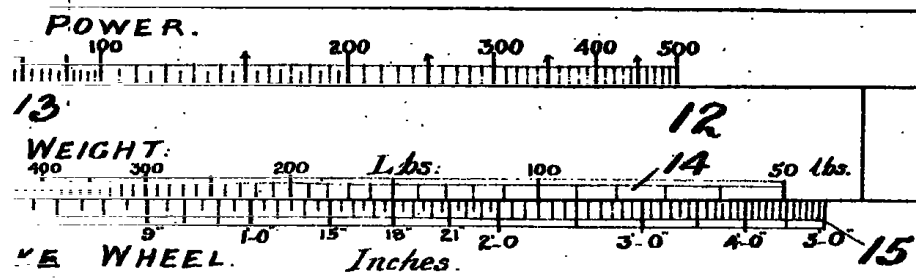


FIG: IV



V

FIG: VI

