[Second Edition.]

A.D. 1863, 26*th* NOVEMBER. N° 2970.

Testing the Strength of Materials and Structures.

LETTERS PATENT to David Kirkaldy, of Glasgow, in the County of Lanark, North Britain, Engineer and Draughtsman, for the Invention of "IMPROVEMENTS IN TESTING OR MEASURING THE STRENGTH AND OTHER PROPERTIES OF VARIOUS MATERIALS AND STRUCTURES, AND IN APPARATUS THEREFOR."

Sealed the 20th May 1864, and dated the 26th November 1863.

PROVISIONAL SPECIFICATION left by the said David Kirkaldy at the Office of the Commissioners of Patents, with his Petition, on the 26th November 1863.

I, DAVID KIRKALDY, of Glasgow, in the County of Lanark, North Britain, Engineer and Draughtsman, do hereby declare the nature of the said Invention of "IMPROVEMENTS IN TESTING OR MEASURING THE STRENGTH AND OTHER PROPERTIES OF VARIOUS MATERIALS AND STRUCTURES AND IN APPARATUS THEREFOR," to be as follows, that is to say:—

This Invention relates to the testing or measuring of the strength and other properties of various materials or structures in a superior and more accurate manner than has been hitherto attained, and to apparatus specially designed with a view to its easy adjustment or adaptation for applying various kinds of strains, and to its accurate measurement or indication of small strains and minute differences of strains as well as of comparatively great strains. It is also arranged that the results obtained by it may be critically verified with the greatest facility.

In one modification of the apparatus for carrying out the Invention three

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hydraulic cylinders, by preference formed in one piece with their rams, are placed horizontally at one end of the machine, the rams being pressed outwards against a cross head having attached to it four powerful rods. The rams are not fixed to the cross head, and they can be used quite independently of each other, either the centre one alone or the two outer ones, or all three according to the strain required. The rams are actuated by preference by three pumps, two of which have the same area but work with their strokes alternating, whilst the third is of larger effective area at first than either of the others, but is contrived so that by detaching a part of its plunger or otherwise, it may afterwards be worked with a smaller effective area. The communications of the pipe from the pumps is by preference with the bottoms of the three cylinders, and a simple screw stop valve is applied to each cylinder. The hydraulic cylinders are fixed at one end of a long sole plate or bed frame which is formed with V-grooves to guide a massive cross head fixed upon the four rods by screw nuts. For applying crushing strains, bending or transverse strains, and compressing, punching, or indenting strains, this cross head is fixed on the rods so as to compress the specimen in the space between it and the cylinders, whilst for applying tensile or drawing and similar strains the specimen is placed on the other side of the cross head to draw the specimen towards the cylinders. The nuts, however, remain at the ends of the rods, and tubular pieces of suitable lengths are put on the rods in halves between the nuts and the cross head to transmit the strain from the nuts to the cross head. In all applications of the apparatus the strain exerted by the rams is opposed or met by a system of levers combined with graduated steelyards, to which weights are applied whereby to accurately measure the strain actually brought to bear on the specimen. The first lever works in a horizontal plane at the end of the machine opposite to the rams, being supported on metal balls or by suspending links, and being acted upon by a T-piece made in two parts which receive the end of the lever between them. In the case of crushing, bending, compressing, or similar strains, the T-piece is connected either by side rods or by upper and lower links to an inner cross head, between which and the main cross head the specimen is placed. In the case of tensile or drawing and of shearing or other similar strains, the specimen is connected to the T-piece outside of or beyond the main cross head. The lever has its fulcrum knife edges bearing in a forked piece fixed to the raised end of the sole plate or bed frame, or it may be made with round pins bearing on anti-friction rollers. The end of the long arm of the lever is connected by a link to a short arm projecting vertically from a horizontal graduated steelyard working in a vertical plane and fitted with appliances for

weighing or measuring the strain transmitted by means of weights. The steelyard may be formed with round journals or pins resting on antifriction wheels, or it may have its bearing by a combination of knife edges on surfaces disposed to meet the various strains. A weight is applied to the non-indicating end of the steelyard to counterbalance the weight of the long arm, so that the minutest strains may be measured, and this weight can be easily removed when the strain to be measured exceeds its amount, so that then so much less weight will require to be put on the yard. For the purpose of measuring greater strains, a second balanced steelyard is arranged above the first, and the strain is transmitted to it from the first by a strut or rod, which can be adjusted out of the way when the upper steelyard is not to be used. The steelyards are marked in the usual way to indicate the strains, and an alarm apparatus is fitted in connection to indicate when a particular or "proof" strain is arrived at in performing an experiment.

Provision is made for measuring and indicating change of form in specimens operated upon, whether by elongation, compression, bending, or otherwise; and the appliance for this purpose consists of two parts connected separately to the cross heads or other parts of the apparatus between which the specimen is placed. One part comprises a rack gearing with a pinion on a dial carried in bearings, which with a stationary pointer form the other part.

Provision is made for indicating through several turns of the dial by forming on it a spiral groove in which there works a small slide acted on by the pointer, and this slide shows in what circle or convolution of the spiral any indication is to be read. In some cases there may be a movement between the part carrying the dial and the specimen, such movement interfering with the indication of the movement, exclusively due to the specimen, and to provide for such cases the pointer ordinarily fixed with a screw may be set free to be moved by a rack acting on a pinion formed on it, such rack being connected to the specimen and correcting any movement of the part carrying the dial. The indicating appliance thus arranged may be fixed on any convenient part of the machine.

For bending specimens or subjecting them to transverse strains the main cross head has fitted to it two blocks, which can be adjusted near to or further from the centre, and whilst these blocks are brought to bear on two parts of the specimen, a third block pressed in the opposite direction is made to bear on the other side of the specimen and between the two other blocks. The blocks may be arranged to grip the specimen.

For applying torsional or twisting strains, the bed frame of the machine is provided with bearings to receive the shaft or spindle to be tested; and in

testing, two toothed wheels are fixed on the spindle, upon which wheels a strain is applied in one direction by means of racks jointed to the main cross head, whilst the opposite strain is received through a lever fixed on the shaft between the two toothed wheels. Adjustable scales to show the amount of movement are put on the wheels, the pointers to such scales being attached to the holding lever, so as to show the total movement. Wheels of different sizes may be applied and at different distances apart, and scales may be put upon suitable parts of the apparatus to measure any change in the length of the specimen. The wheels may be acted upon by chains or other jointed or flexible connections.

To measure the force actually concerned in applying bursting or collapsing strains by fluid pressure, a cylinder is fitted to the chamber or vessel into which the water or fluid used in the operation is forced, and which vessel will be the vessel or structure to be tested in the case of a bursting strain, but will contain the vessel or structure to be tested in the case of a collapsing strain. The cylinder is fitted with a piston, and the chamber or vessel is placed in the machine in such a way that the rod of the piston may communicate the pressure on its area through the T-piece and lever to the steelyards. If the pressure of the atmosphere is to be used in collapsing the specimen or vessel, the cylinder and piston is arranged in the machine in such a way that the piston will be drawn outwards relatively to the vessel by the action of the hydraulic rams, and so tend to produce a vacuum inside the vessel, water or other liquid being contained therein.

The machine may also be used for measuring and indicating change of form or strength in a specimen when subjected to heat or cold, as the apparatus for applying the heat or cold may be easily introduced into the machine in such a way that the specimen under experiment may act on or be acted on by one or both cross heads.

It is an important feature of the improved apparatus that the specimens operated upon are placed in a horizontal position, which has many practical advantages, and amongst other things it admits of the application of combinations of strains. Thus percussive, vibratory, jarring, and other strains may be applied to the specimens whilst subjected to any desired degree of tensile, transverse, compressive, or similar strains brought to bear by any of the means herein-before described.

When the apparatus is not required to apply great strains, one or two hydraulic cylinders or a screw or combination of screws may be substituted for the three hydraulic cylinders herein-before described.

Kirkaldy's Improvements in Testing the Strength of Materials and Structures.

SPECIFICATION in pursuance of the conditions of the Letters Patent, filed by the said David Kirkaldy in the Great Seal Patent Office on the 26th May 1864.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, DAVID KIRKALDY, of Glasgow, in the County of Lanark, North Britain, Engineer and Draughtsman, send greeting.

WHEREAS Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Twenty-sixth day of November, in the year of our Lord One thousand eight hundred and sixty-three, in the Twenty-seventh year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said David Kirkaldy, Her special licence that I, the said David Kirkaldy, my executors, administrators, and assigns, or such others as I, the said David Kirkaldy, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "IMPROVEMENTS IN TESTING OR MEASURING THE STRENGTH AND OTHER PROPERTIES OF VARIOUS MATERIALS OR STRUCTURES, AND IN APPARATUS THEREFOR," upon the condition (amongst others) that I, the said David Kirkaldy, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that I, the said David Kirkaldy, do hereby declare the nature of my said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement in writing, reference being had to the accompanying Drawings, and to the letters and figures marked thereon, that is to say:—

My said Invention relates to the testing or measuring of the strength and other properties of various materials and structures in a superior and more accurate manner than has been hitherto attained, and to apparatus specially designed with a view to its easy adjustment or adaptation for applying various kinds of strains, and to its accurate measurement or indication of small strains and minute differences of strains, as well as of comparatively great strains.

It is also so arranged that the results obtained by it may be critically verified with the greatest facility.

And in order that my said Invention and the manner of performing the same may be properly understood, I have hereunto appended three Sheets of explanatory Drawings to be herein-after referred to, and representing modifications of my improved apparatus and arrangements.

In one modification of the apparatus for carrying out my Invention three hydraulic cylinders, by preference formed in one piece, are placed horizontally at one end of the machine, the rams being pressed outwards against a cross head having attached to it four powerful rods. The rams are not fixed to the cross head, and they can be used quite independently of each other, either the centre one alone, or the two outer ones, or all three according to the strain required. The rams are actuated by three pumps, and in one modification two of these have the same area, but work with their strokes alternating, whilst the third is of larger effective area at first than either of the others, but has a well-known arrangement for detaching a part of its plunger, so that it may afterwards be worked with a smaller effective area. The communications of the pipe from the pumps is, by preference, with the bottoms of the three hydraulic cylinders, and a simple screw stop valve is applied to each cylinder In some cases one or two hydraulic cylinders, or a screw or combination of screws may be substituted for the three hydraulic cylinders herein-before described; and in the modification represented in the accompanying Drawings a single hydraulic cylinder has been adopted.

Figure 1 is a plan of the machine with the strain-indicating apparatus in horizontal section; and Figure 2 is a longitudinal vertical section of the main part of the machine; Figure 3 is a side elevation of the strain-indicating apparatus with the framing in vertical section; and this apparatus is shown in transverse vertical section in Figure 4, and in end elevation in Figure 5. Figure 5 also comprises a transverse vertical section of the main machine as taken at the line A, A, in Figures 1 and 2; and Figures 6 and 7 are transverse vertical sections taken at the lines B, B, and C, C, in Figures 1 and 2. Figures 8, 9, and 10 on Sheet 2, are transverse vertical sections taken at the lines D, D, E, E, and F, F, in Figures 1 and 2, Figures 9 and 10 containing details not shown in Figures 1 and 2, but herein-after more particularly referred to. The remaining Figures on Sheets 2 and 3 will be more conveniently referred to after describing the main features of the machine.

The hydraulic cylinder 1 is fixed at one end of a long sole plate or bed frame 2, which, for convenience, is cast in four separate parts, securely and

rigidly bolted to each other, and held down by tie bolts to a massive foundation of masonry. The bed frame is formed with V-grooves along the sides to guide the cylinder cross head 3, which has attached to it the four rods 4, and to guide a second cross head 5, which is fixed by screw nuts on the rods 4, these being screwed for the purpose. For applying crushing strains, bending or transverse strains, and compressing, punching, or indenting strains, this cross head 5 is fixed on the rods 4 in such a position as to compress the specimen S in the space between it and the cylinder 1, whilst for applying tensile or drawing and similar strains, the specimen is placed on the other side of the cross head 5 to draw the specimen towards the cylinder 1.

In Figure 1 the machine is shown as applying a bending strain to a specimen S. The rods 4 are represented as screwed for a considerable portion of their length, in order that the cross head 5 may be adjusted upon them in any convenient position; and to facilitate such adjustment provision is made for working the four screw nuts simultaneously, they being formed with pinion teeth connected by intermediate toothed wheels, and worked by a hand shaft 6 through a pair of bevil pinions. The working of the nuts back and forwards may be avoided by applying tubular pieces of suitable lengths to be put on the rods in halves between the nuts and the cross head, as herein-after more particularly described, in which case the nuts might always remain at the ends of the rods, the tubular pieces transmitting the strain to them from the cross head when this is placed nearer to the cylinder. In all applications of the apparatus the strain exerted by the cylinder 1 is opposed or met by a system of levers combined with graduated steelyards, to which weights are applied to accurately measure the strain actually brought to bear on the specimen. The first lever 7 works in a horizontal plane at the end of the machine opposite to the cylinder 1, being supported on metal balls or struts or by suspending links, and being acted upon by a T piece 8 made in two parts, which receive the lever 7 between them. In the case of crushing, bending, compressing, or similar strains, the T piece 8 is connected either by side rods or by upper and lower links 9, as shown in Figures 1 and 2, to an inner cross head or block 10, between which and the main cross head 5 the specimen S is placed. In the case of tensile, or drawing, and of shearing, and other similar strains, the specimen is connected to the T piece 8 outside of or beyond the main cross head 5. The strain of the T piece is communicated to a vertical pin 11 fixed in the lever 7, and fitted with steel knife edges, which bear against steel pieces fitted in eyes which are formed in the upper and lower parts of the T piece to receive the pin 11. The fulcrum knife edges of the lever 7 are fitted upon a similar pin 12 fixed in the lever, and they bear upon steel pieces

fitted in eyes formed in a forked piece 13 fixed to the raised end 14 of the bed frame 2. The strain acting between the end of the bed frame and the abutment 15, against which the inner end of the cylinder 1 bears, is met by two cast-iron rods 16, as well as by the bottom of the bed frame itself. These rods 16 are keyed at one end in the abutment 15, and at the other end in an abutment 15^1 formed on the bed frame, and connected by side bars to the raised end or abutment 14. The first lever 7 is represented (Figure 5) as supported by struts 17, 18, at each end, the lever being fitted with knife edges to bear on the struts, and the struts bearing on knife edges on the bed frames; and this arrangement admits of the very slight movements of the lever with the least friction. The end of the long arm of the lever 7 is connected by a link 19 to a short arm 20 projecting vertically downwards from a horizontal graduated steel yard 21 working in a vertical plane, and fitted with appliances for weighing or measuring by means of weights the strain transmitted. The link 19 is connected to the first lever 7 by means of upper and lower plates connected together, and to the lever by pins, and formed with eyes, into which a pin in the lever is entered, and on steel pieces in which knife edges on the pin bear. The link is connected to the steelyard 21 in a similar way.

The steelyard 21 may be formed with round journals or pins resting on antifriction wheels, but I prefer to construct it with a combination of knife edges bearing on surfaces disposed to meet the various strains, as herein-after more particularly described. A weight 22 is applied to the non-indicating end of the steelyard 21 to counterbalance the weight of the long arm, so that the minutest strains may be measured, and this weight can be easily removed when the strain to be measured exceeds its amount, so that then as much less weight will require to be put upon the yard. For the purpose of measuring greater strains a second balanced steelyard 23 is arranged above the first, and the strain is transmitted to it from the first by a strut or rod 24, which can be adjusted so as to be inactive when the upper steelyard is not to be used. The strut 24, which is shown enlarged in side and front views in Figures 54, 55, Sheet 3, is forked at both ends, and the strain is communicated by knife edges on the lower yard, and is received by knife edges on the upper one. The strut is in two pieces, which are keyed together, and when it is to be inactive the parts are keyed together in such a way as to shorten it, whilst the upper parts being looped round the upper knife edges, it is prevented from falling. The steelyards 21, 23, are marked in the usual way, and are provided with weights 25, 26, to indicate the strains, and a bell alarm apparatus is fitted in connection with each yard to indicate when a particular or "proof" strain is arrived at in performing an experiment. The weights are easily

moved along the yards by means of endless cords passed round pulleys at each end, and actuated by small hand wheels 27, 28. The yards are carried by two standards 29, 30, each of which is formed in two pieces, so as to enclose the yards between them, and with openings for the points of the yards to work in, these openings being fitted with wooden striking pieces for the yards to come in contact with when any sudden movement takes place from a specimen giving way, or otherwise. With a similar object wooden striking pieces are also fitted in the eyes of the T-piece 8 and on the raised abutment 14, where the T-piece would strike.

Provision is made for measuring and indicating change of form in the specimens operated upon, whether by elongation, compression, bending, or otherwise ; and the appliance for this purpose consists of two parts to be connected separately to the cross heads or other parts of the apparatus between which the specimen is placed.

A convenient modification of this appliance is shown in section in Figure 48, Sheet 3, and in face view in Figure 49. One part comprises a rack 47 to be connected to the specimen or to one of the cross heads, and gearing with a pinion fixed to a dial 48, which is carried by and can turn on a stud 49 fixed to the framing or to the opposite cross head. On the stud 49 there is fixed a pointer 50, which is usually stationary, and forms the other part of the appliance. Provision is made for indicating through several turns of the dial 48 by forming on it a spiral groove, in which there works a small slide *a*, acted on by the pointer 50, and this slide shows in what circle or convolution of the spiral any indication is to be read. In some cases there may be a movement between the part carrying the dial and the specimen, such movement interfering with the indication of the movement exclusively due to the specimen, and to provide for such cases the pointer 50, ordinarily fixed with a screw, may be set free to be moved by a rack 51 acting on a pinion formed on it, such rack being connected to the specimen and correcting any movement of the part carrying the dial. The indicating appliance thus arranged may be fixed on any convenient part of the machine. For bending specimens, or subjecting them to transverse strains, the main cross head 5 has fitted to it two blocks 31, which can be adjusted nearer to or further from the centre, and whilst these two blocks 31 are brought to bear on two outer parts of the specimen S, a third block 10 pressed in the opposite direction is made to bear on the other side of the specimen and between the two other blocks 31. When it is wished to act on the specimen at points further apart than can be obtained with the cross head 5, a larger cross head 32 can be fixed upon the cross head 5, as shown in Figure 11, Sheet 2. The blocks 31 may be

arranged to grip the specimen. For applying torsional or twisting strains the bed frame of the machine is provided with bearings to receive the shaft or spindle to be tested, and in testing two toothed wheels are fixed on the spindle, upon which wheels a strain is applied in one direction by means of racks jointed to the main cross head, whilst the opposite strain is received through a lever fixed on the shaft between the two toothed wheels. Wheels of different sizes may be applied, and at different distances apart, and scales may be put upon suitable parts of the apparatus to measure any change in the length of the specimen. The wheels may be acted upon by chains or other jointed or flexible connections. The arrangements for testing short or small spindles are shown in transverse vertical section in Figure 9, Sheet 2, already referred to, and in plan and longitudinal vertical section in Figures 12 and 13, Sheet 2. The spindle S 33 is placed in bearings on the bed frame just within the V-grooves, and the wheels 34 are fixed on it close to the inner sides of the bearings, whilst the holding back lever 35 is fixed on the middle. The twisting strain is applied to the wheels 34 by a pair of racks 36 jointed to holders, which are keyed to the main cross head 5, and the racks are held down upon and in gear with the wheels by a spindle 37 held by a pair of standards fixed to the framing. The holding-back lever 35 is connected by a link 38 to the T-piece 8, through which the strain is transmitted to the steel-yards and measured. When it is wished to apply and measure a torsional strain on a larger or longer shaft than can be conveniently arranged, as shown in Figure 9, the shaft S to be tried is placed in bearings 39 at the under side of the bed frame, and it has fixed upon it larger wheels 40, as shown in Figure 10, and also in Figure 14, the former being a transverse vertical section, and the latter a plan. The wheels 40 can be applied at different distances from the middle of the shaft, as indicated by the dotted lines, brackets 41 being fixed to the sides of the bed frame to carry adjustable cross-frame bars 42 formed with bearings for the shaft, and fitted with standards 43 to receive the holding-down bar 44, by which the racks are kept in gear. The holding-back lever 46 fixed on the middle of the shaft is connected to the T-piece 8 in the same way as the smaller one. Adjustable scales, such as the one shown in face view and section in Figures 50, 51, Sheet 3, are put on the wheels, the pointers to such scales being by preference attached to the holding-back lever 35 or 46, so as to show the total movement. The scales are by preference adjusted after sufficient strain is applied to bring the parts to a fair bearing.

Figures 52, 53, Sheet 3, are face view and section of the appliance which I prefer for indicating any end movement of a shaft or spindle subjected to

torsion, and suitable for indicating movement exhibited by specimens tested in various ways. This appliance comprises a stationary adjustable dial 52, with a pointer 53, the boss of which latter is made with pinion teeth to gear with a rack by which the movement of the specimen is communicated. A small slide *b* is fitted to work in a groove in the dial, being moved forward by the pointer, but if the specimen recovers some of its movement on the strain being removed, the slide remains at the maximum, and the difference between its position and the final position of the pointer, shows the extent of the recovery.

The manner of applying compressive strains to specimens in various ways is shown in Figures 15 to 22, Sheet 2. Figure 15 is a sectional plan, and Figure 16 is a corresponding longitudinal vertical section, showing a long bar S being compressed, and if buckling is to be prevented during the compression, the appliances hitherto used for that purpose may be added; Figure 17 represents in horizontal section a block of brickwork being compressed; Figures 18 and 19, are sections showing punching or indenting; and Figure 20 is a section, showing the bursting of a small ring or ferrule by compressing into it a tapered mandril. Figures 21, 22, are horizontal and vertical sections showing the compressing of a ring or hoop S. The manner of applying tensile or drawing strains to specimens in various ways is shown in Figures 23 to 32, Sheet 2. Figures 23 and 24, are horizontal and vertical sections, showing a long rod or bar S as being subjected to drawing the ends of the rod being fixed by wedges in blocks 5', which are linked to the cross head 5, and T-piece 8 respectively; Figure 25 is a section showing the connecting of a flat specimen S directly to the cross head and T-piece by pins passing through eyes in it; Figures 26 and 27 are vertical and horizontal sections showing the manner of testing the strength of a rivetted plate joint S, and Figures 28 and 29, are horizontal and vertical sections showing an arrangement for applying a shearing strain to a bolt or bar S. Figure 30 is a vertical section, showing an arrangement for applying a tensile strain to a small rod or bar S with heads; and Figures 31 and 32 are horizontal and vertical sections, showing the manner of applying an elongating or pulling strain to a ring or hoop S. The parts of the machine which are shown in these Figures, are marked with the same reference numerals as in the more complete representations of the machine, so that there may be no difficulty in understanding how the various kinds of strains are to be applied in the complete machine, and this remark also applies to what follows.

To measure the force actually concerned in applying, bursting, or collapsing strains by fluid pressure, arrangements are used such as are shown in section in Figures 39 to 43, Sheet 3, in which a cylinder 55 is fitted to the chamber

or vessel 56, into which the water or fluid used in the operation is forced (by a pipe 57 from any suitable force pump), and which vessel will be the vessel or structure S to be tested in the case of a bursting strain (Figures 39, 40,) but will contain the vessel or structure S to be tested in the case of a collapsing strain (Figures 42, 43). The cylinder 55 is fitted with a piston 58, and together with the chamber or vessel 56 is placed in the machine in such a way that the rod of the piston 58 may communicate the pressure on its area by the cross head 10, and rods 9 to the T-piece (8, not shown in these Figures,) and thence through the lever (7) to the steelyards. If the pressure of the atmosphere is to be used in collapsing the specimen or vessel, the cylinder and piston (55, 58,) is arranged in the machine in such a way that the piston will be drawn out relatively to the vessel by the action of the hydraulic rams, and so tend to produce a vacuum inside the vessel, water or other suitable liquid being contained therein.

The machine may also be used for measuring and indicating change of form or strength in a specimen when subjected to heat or cold, as the apparatus for applying the heat or cold may be easily introduced into the machine in such a way that the specimen under experiment may act on or be acted on by one or both cross heads 5 or 10.

Figure 36, Sheet 3, is a longitudinal vertical section of a boiler or heating vessel for applying heat by means of water, oil, or other liquid, to a specimen S, arranged in blocks 54 for being subjected to a tensile strain when at various temperatures. A gas pipe 59, with numerous jets, is shown as the means for heating the boiler, but other means for that purpose may obviously be adopted. For applying great heat the apparatus shown in transverse and longitudinal vertical section in Figures 37 and 38, Sheet 3, may be adopted. It consists of a vessel lined with fire-brick, to receive fuel to be applied directly to the specimen, an air pipe 60, with tuyeres, being provided for blowing the air in. Pyrometers are provided for indicating the heat, and also apertures in which fusible plugs of different metals or alloys may be placed to indicate temperature by their melting.

It is an important feature of my improved apparatus that the specimens operated upon are placed in a horizontal position, which has many practical advantages, and amongst other things it admits of the application of combinations of strains; thus percussive, vibratory, jarring, and other strains may be applied to the specimens whilst subjected to any desired degree of tensile, transverse, compressive, or similar strains brought to bear by any of the means herein-before described.

Figure 33, Sheet 3, represents in sectional elevation a convenient arrange-

ment for subjecting a specimen bar S to the action of a falling weight 61, or a resting weight 62, whilst being drawn or compressed in the machine.

Figure 34 is a transverse vertical section, and Figure 35 is sectional side elevation, showing a convenient means for imparting to a specimen S a succession of blows with a weight 61 by a rotating cam 63, whilst at 64, 65, and 66 are indicated examples of the various forms of cams that may be used.

The manner in which I prefer to dispose the fulcrum knife edges of the steelyard 21 is shown upon an enlarged scale in Figures 44, 45, 46, 47. Sheet 3, Figure 44, showing in vertical section the fulcrum pin 67, and the pin 68 of the short vertical arm 20, whilst Figure 45 is a back view of the pins 67, 68, and Figures 46, 47, are two sections of the fulcrum pin 67. This fulcrum pin 67 rests on two pairs of steel pieces 69, 70, one of each pair being on each side of the yard; the inner pair 69 receiving the main strain at an angle of 45 degrees, and the outer pair bearing up vertically the weight of the parts.

Figures 56 and 57, Sheet 3, are sectional end and side views of one modification of tubular pieces to be put on the rods 4 to suit different positions of the cross heads when the rods 4 are not screwed; and Figures 58 and 59 are sectional side and end views of another modification. The tubular pieces are made in different lengths and in halves, and are connected together endways by pins, as shown in Figures 56, 57, or the halves of each pair are connected together by screw bolts, as shown in Figures 58, 59.

Having thus particularly described my said Invention, and the manner in which the same is or may be performed, I have to state that I do not restrict myself to the precise details herein described or delineated; and that I do not claim to have invented every separate detail herein described and delineated; but that what I believe to be novel and original, and claim as the Invention secured to me by the herein-before in part recited Letters Patent, is,—

1. The testing or measuring of the strength and other properties of various materials and structures by means of apparatus, the parts of which are arranged or combined together, substantially in the improved manner herein-before described.

2. The contriving and arranging of testing apparatus, so that the parts can with facility be changed or adjusted for applying various kinds of strains to specimens of various sizes, kinds, and materials, substantially in the manner herein-before described.

3. The employing of a lever working in a horizontal plane for communicating the strain to the steelyards, substantially as herein-before described.

4. The adapting to testing apparatus of a dial with a spiral groove and slide for indicating elongation, contraction, or other like change in a specimen, so as in a compact form to give an enlarged indication capable of extending over considerable lengths, substantially as herein-before described; and,

5. The using of a cylinder and piston (55, 58,) for transmitting and measuring the exact fluid pressure in expanding or collapsing hollow vessels or structures, substantially in the manner herein-before described, more particularly with reference to Figures 39 to 43 on Sheet 3 of the accompanying Drawings.

In witness whereof, I, the said David Kirkaldy, have hereunto set my hand and seal, this Twenty-fourth day of May, in the year of our Lord One thousand eight hundred and sixty-four.

DAVID KIRKALDY. (L.S.)

Witness,

EDMUND HUNT, Patent Agent,
28, St. Enoch Square, Glasgow.

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KIRKALDY'S SPECIFICATION.

(2nd Edition)

3 SHEETS,
SHEET 1

FIG. 6.
Section at A–A.

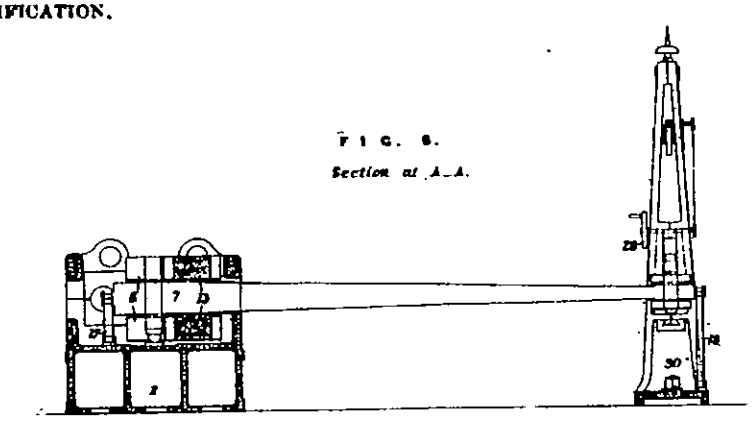


FIG. 4.

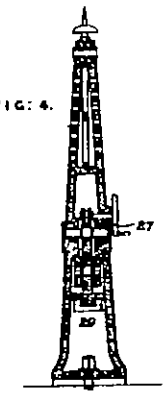
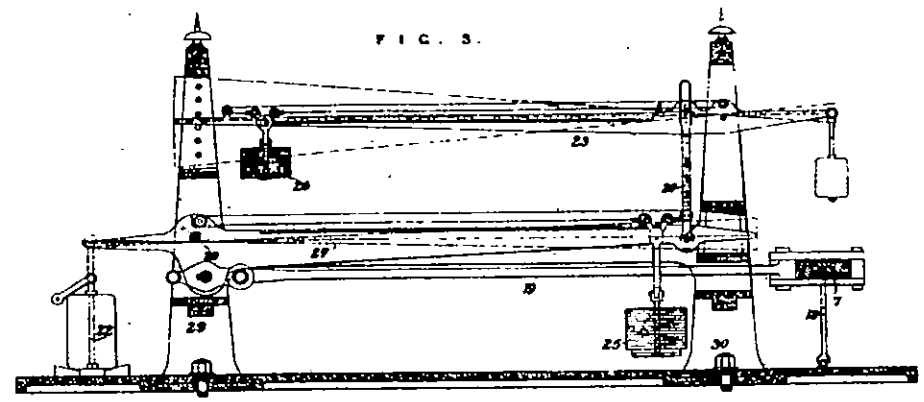


FIG. 5.



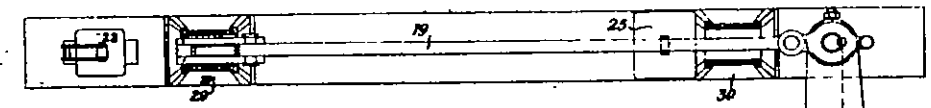


FIG. 8.
Section at B–B.

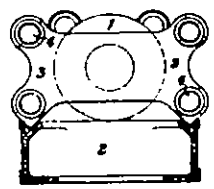


FIG. 7.
Section at C.C.

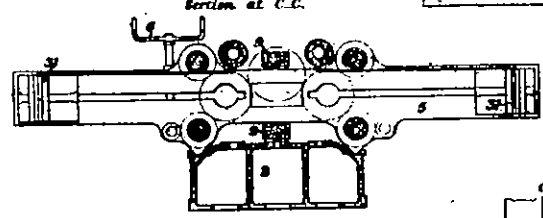


FIG. 1.

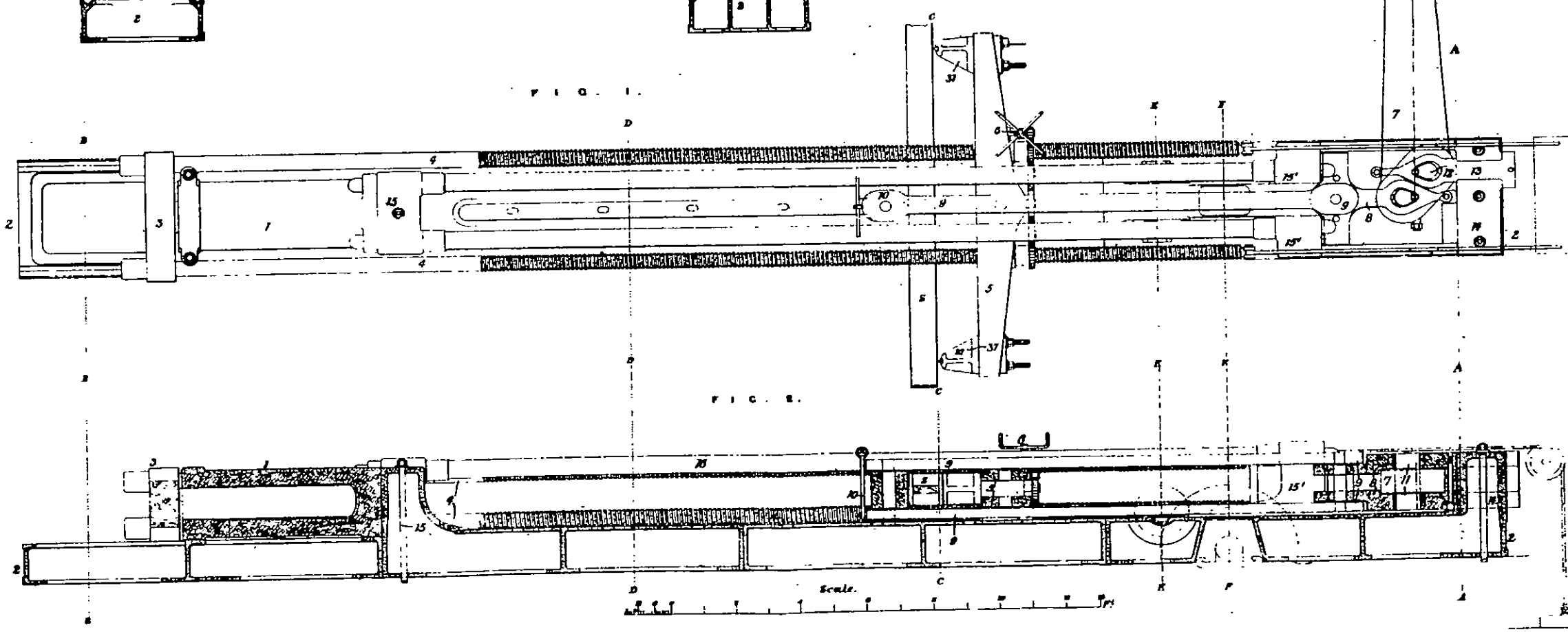


FIG. 2.

Scale.

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KIRKALDY'S SPECIFICATION.

(2nd Edition)

(3 SHEETS, SHEET 2.

Part I.

FIG. 15.

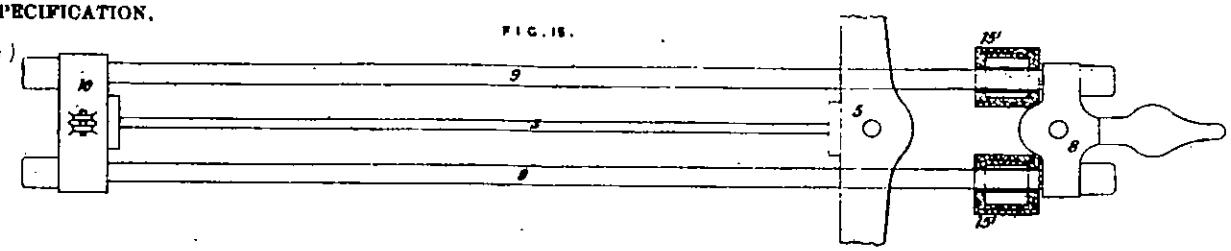


FIG. 16.

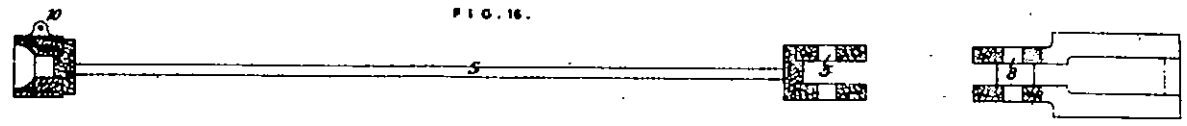


FIG. 17.

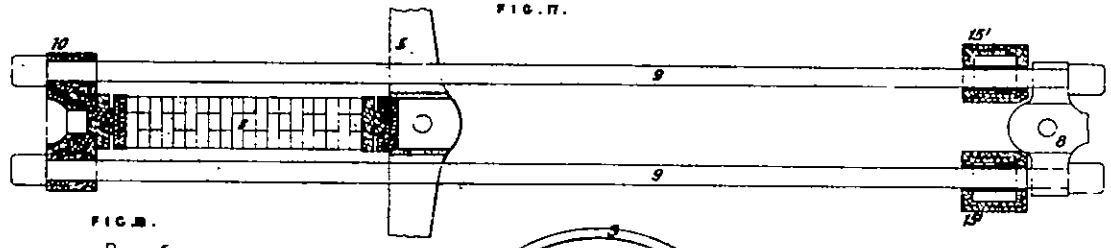


FIG. 8.

Section at D.D.

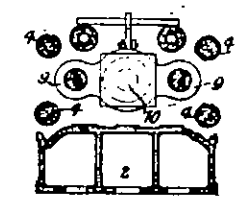


FIG. 19.

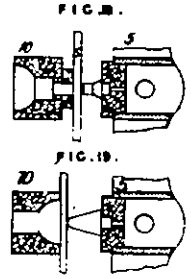


FIG. 21.

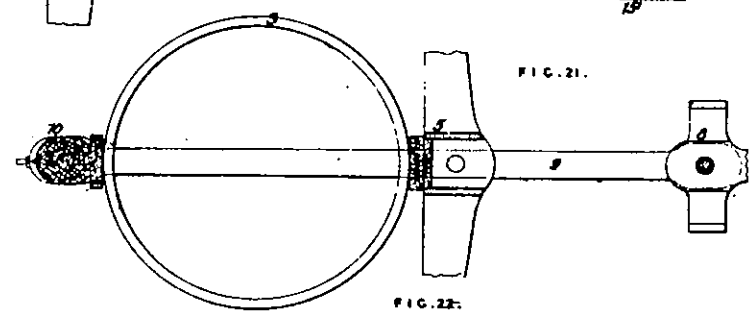


FIG. 9.

Section at E.E.

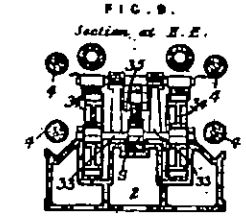


FIG. 20.

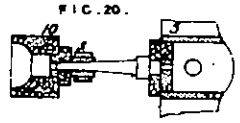


FIG. 22.

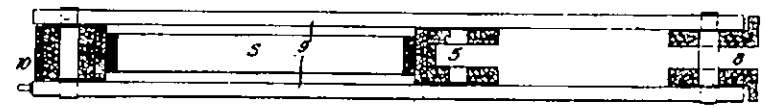


FIG. 10.

Section at F.F

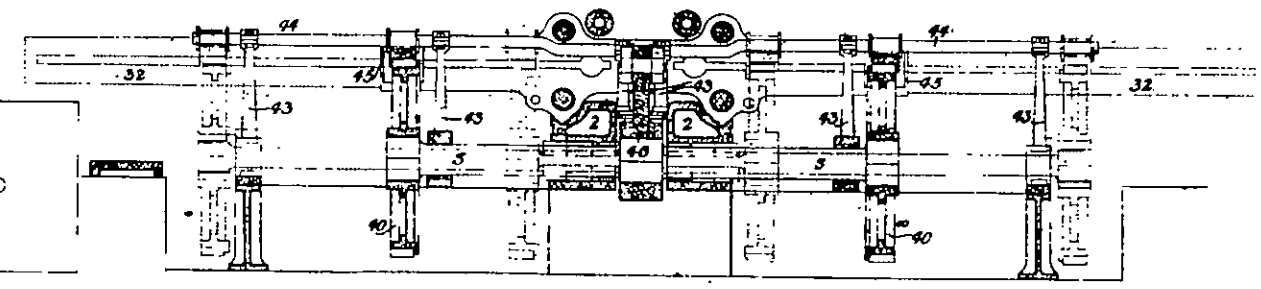


FIG. 12.

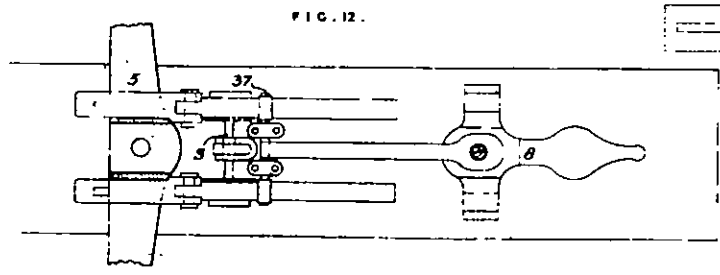


FIG. 13.

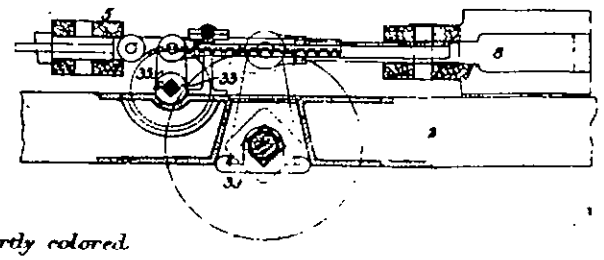
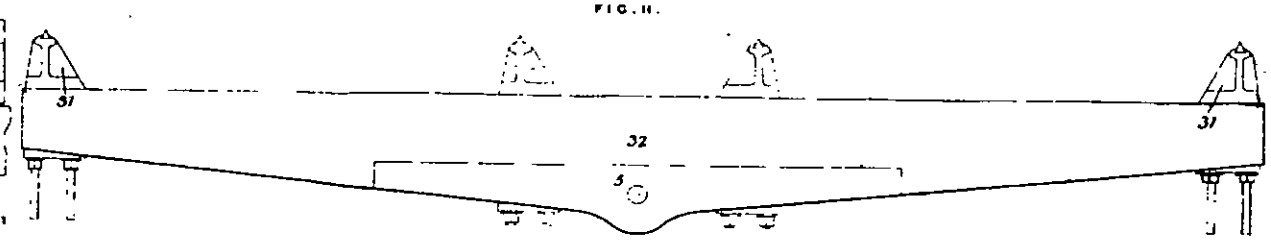


FIG. 11.



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KIRKALDY'S SPECIFICATION.

(2nd Edition.)

(3 SHEETS)
SHEET 2.

Part 2.

FIG. 23.

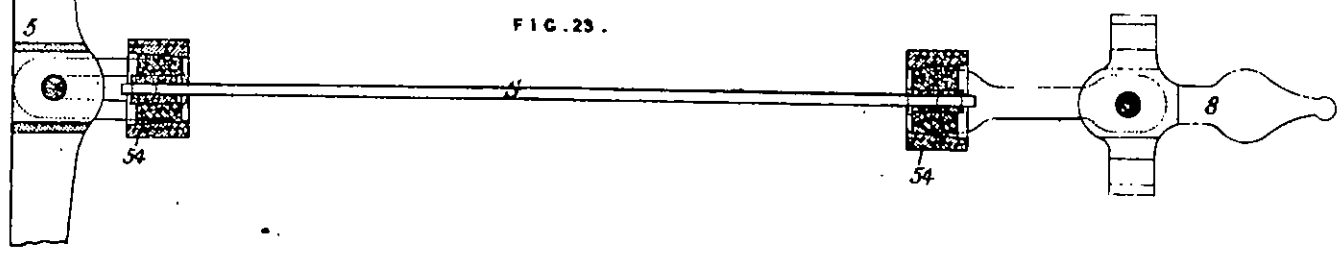


FIG. 24.

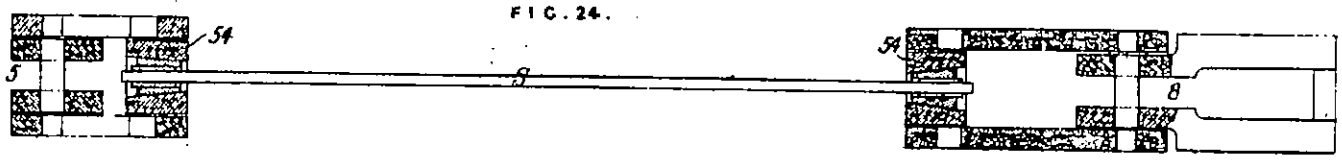


FIG. 25.

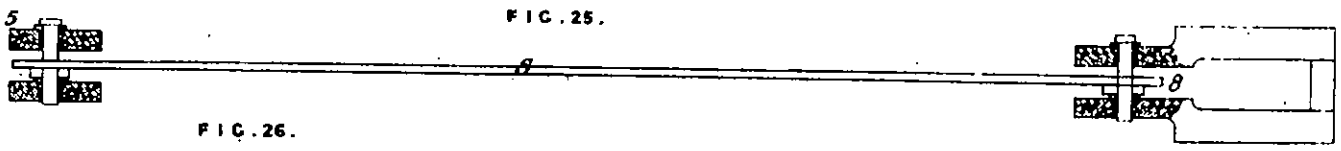


FIG. 26.

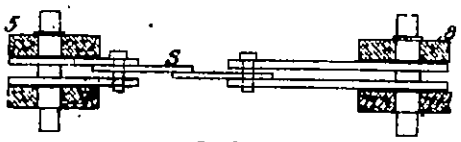


FIG. 30.

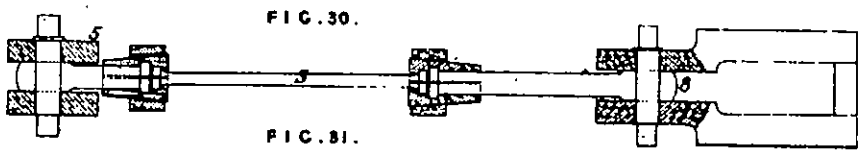


FIG. 27.

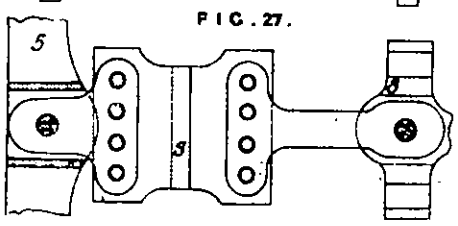


FIG. 28.

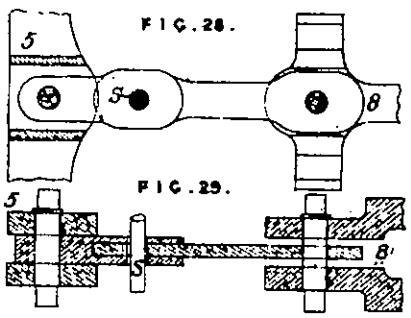


FIG. 29.

FIG. 31.

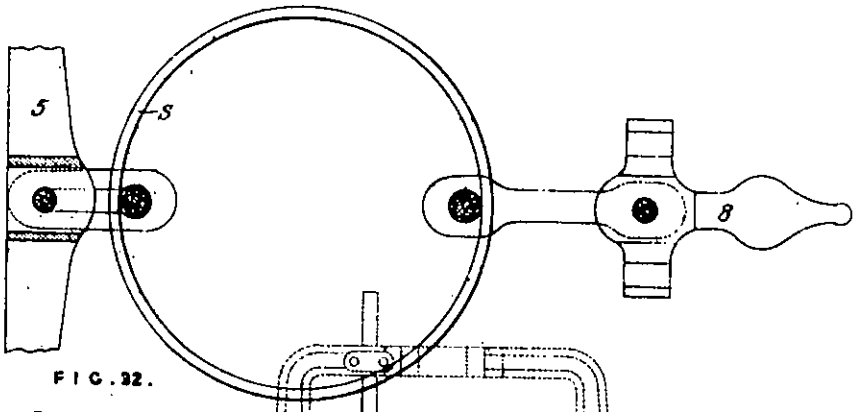
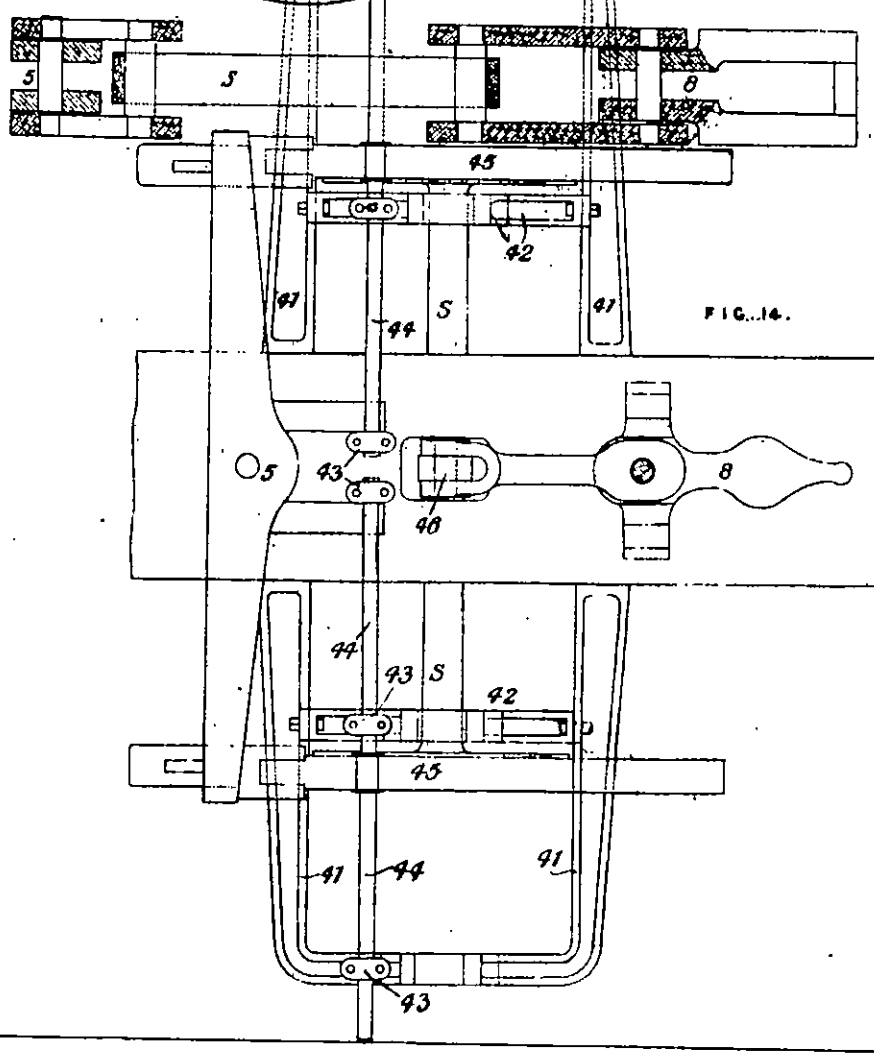


FIG. 32.



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KIRKALDY'S SPECIFICATION.

(2nd Edition)

(3 SHEETS, SHEET 3.

Part 1.

FIG. 33.

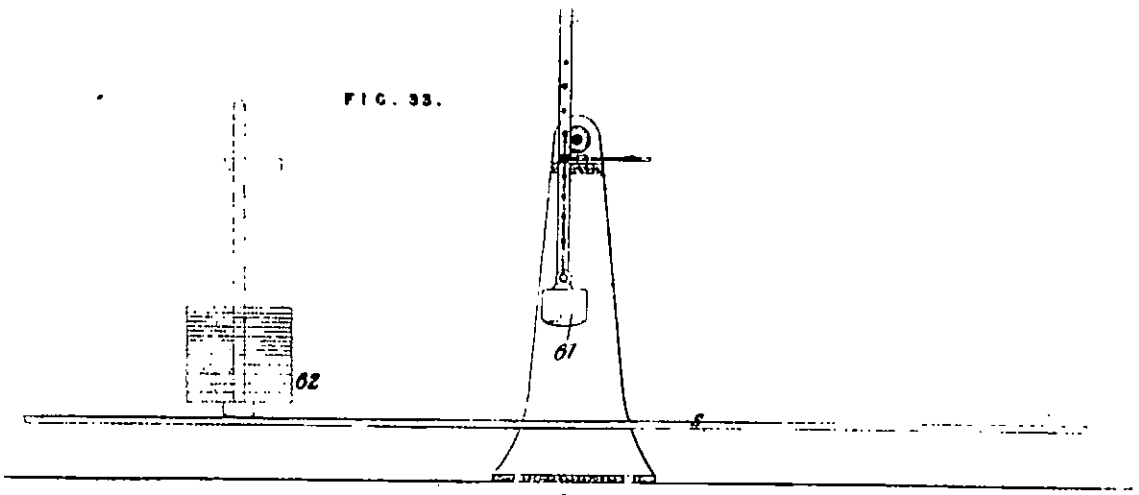


FIG. 34.

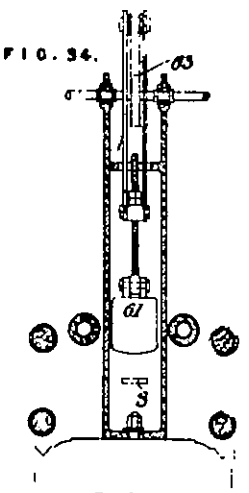


FIG. 35.

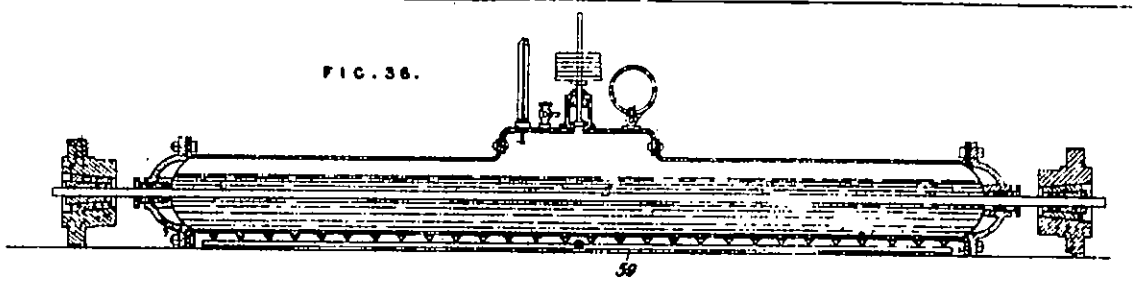


FIG. 37.

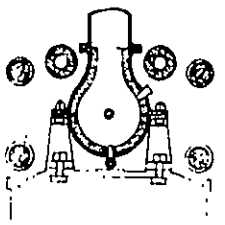


FIG. 39.

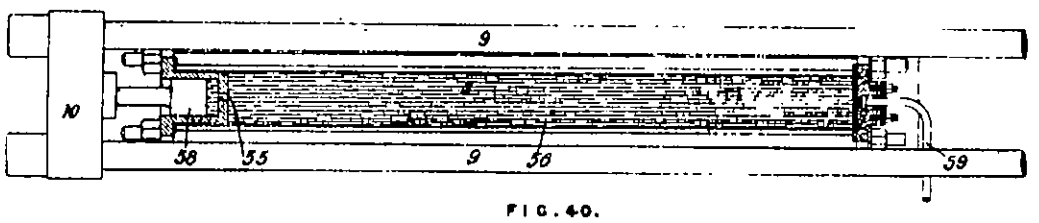


FIG. 41.

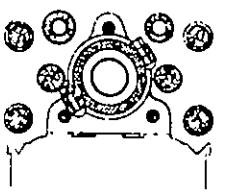


FIG. 40.

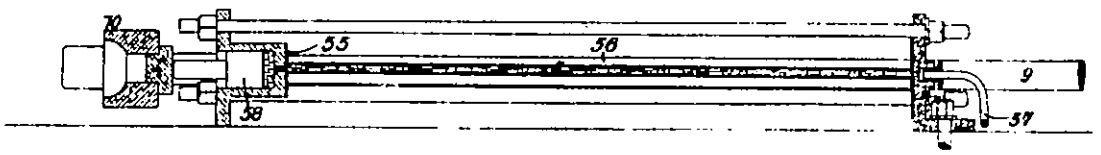


FIG. 45.

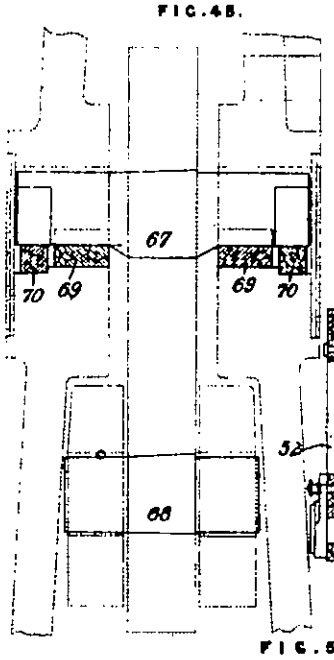


FIG. 48

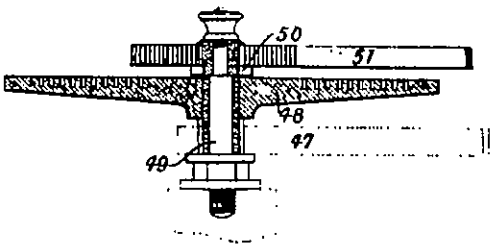


FIG. 44.

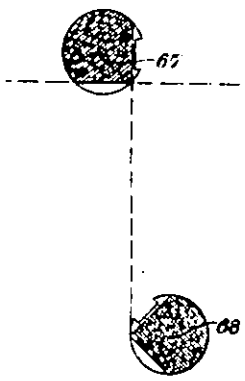


FIG. 46.

FIG. 47.

FIG. 49.

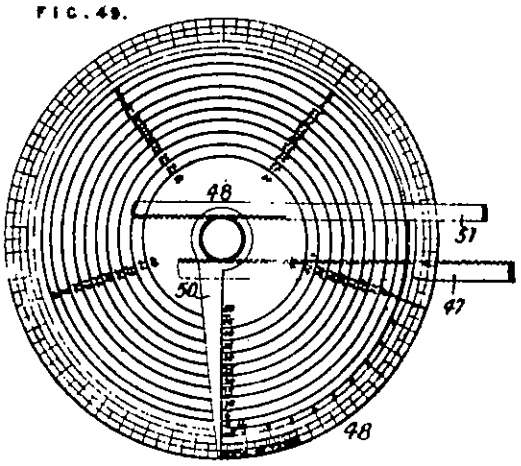


FIG. 53.

FIG. 52.

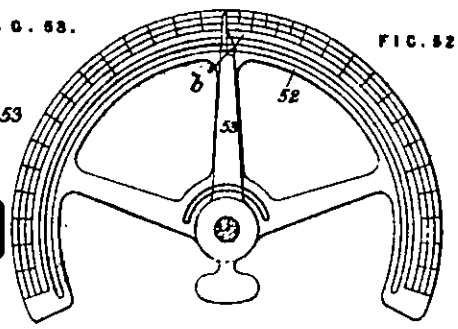
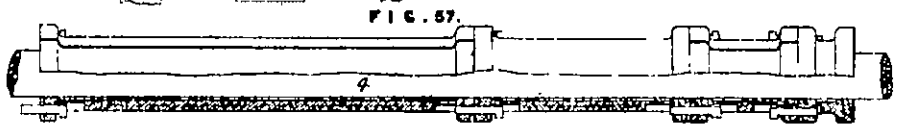


FIG. 56.

FIG. 57.



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KIRKALDY'S SPECIFICATION.

(2nd Edition)

(3 SHEETS)
SHEET 3
Part 2

FIG. 35.

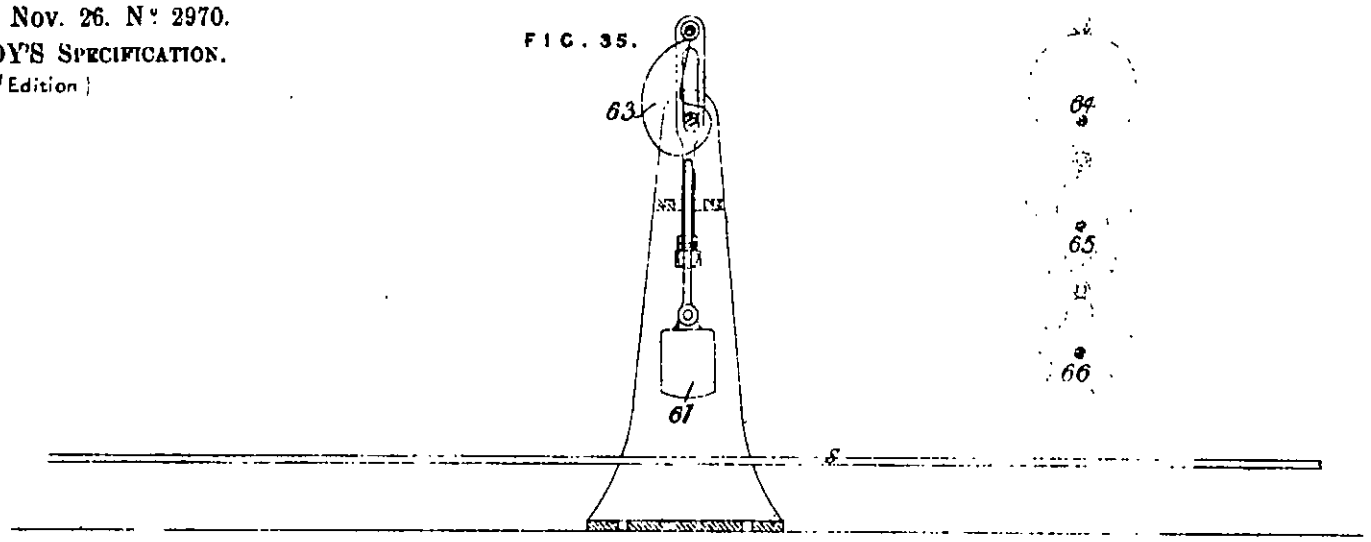

FIG. 38.

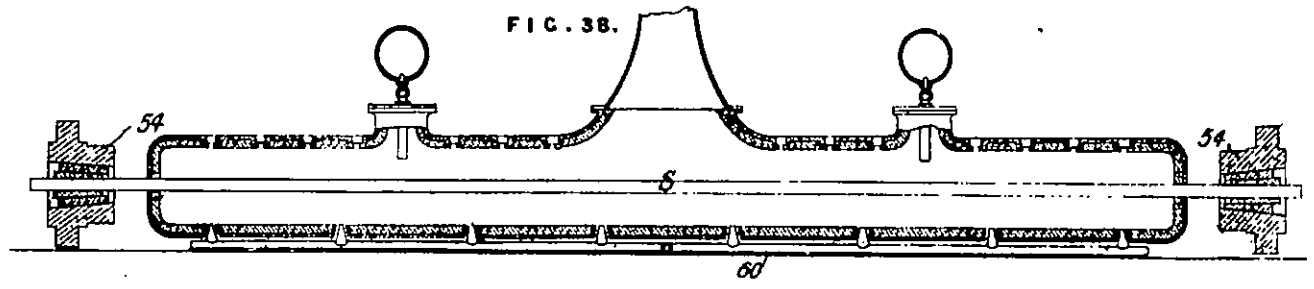

FIG. 42.

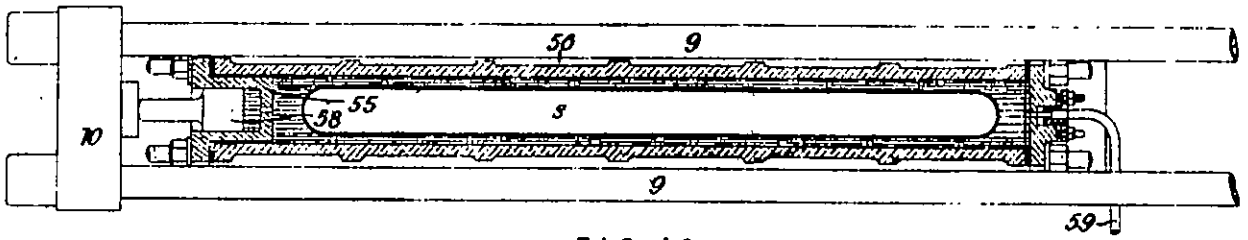

FIG. 43.

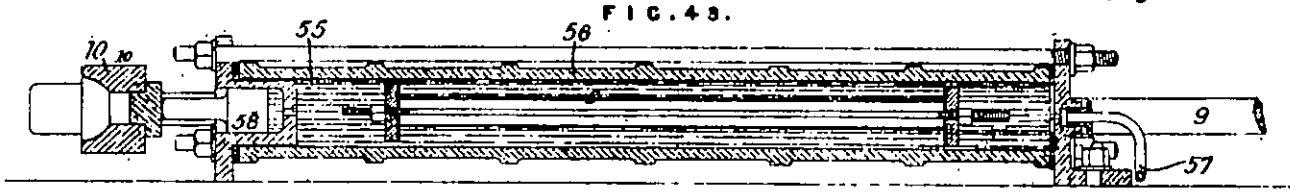

FIG. 54.

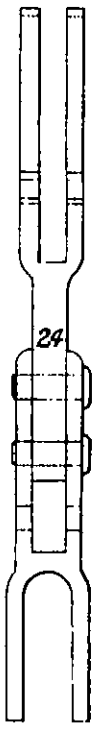

FIG. 55

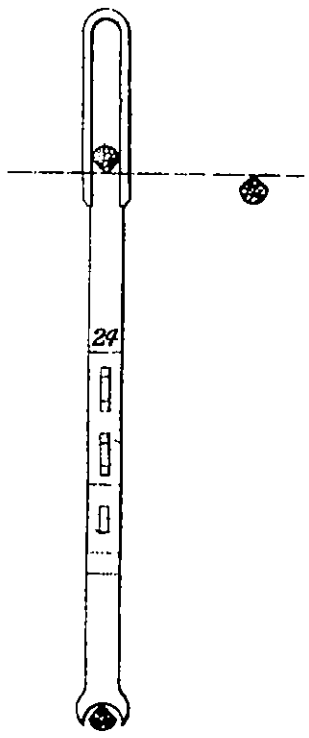

FIG. 50.

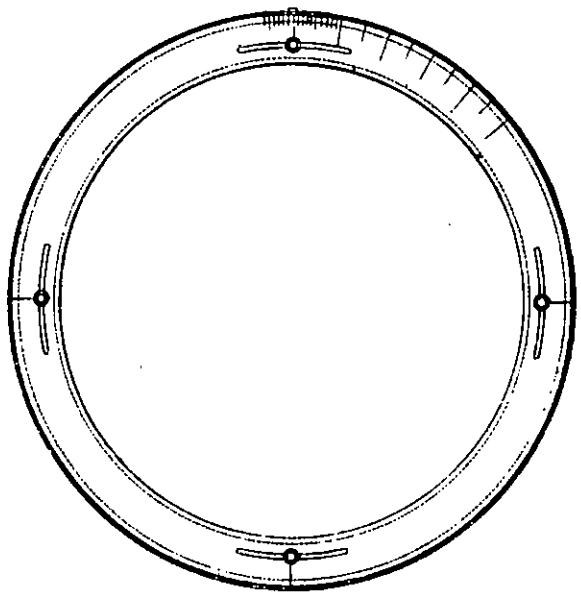

FIG. 51

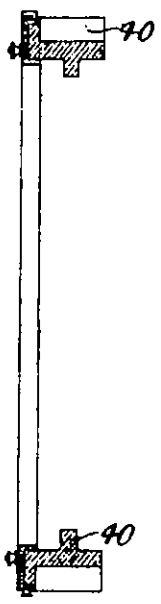

FIG. 56.

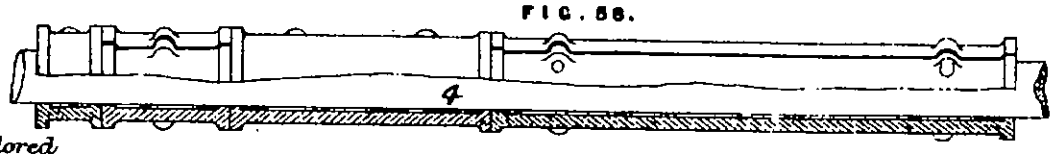

FIG. 59.

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