H. C. SNOOK.

X-RAY SYSTEM.

APPLICATION FILED JULY 20, 1907.

954,056.

Patented Apr. 5, 1910.

3 SHEETS—SHEET 1.

Fig. 1

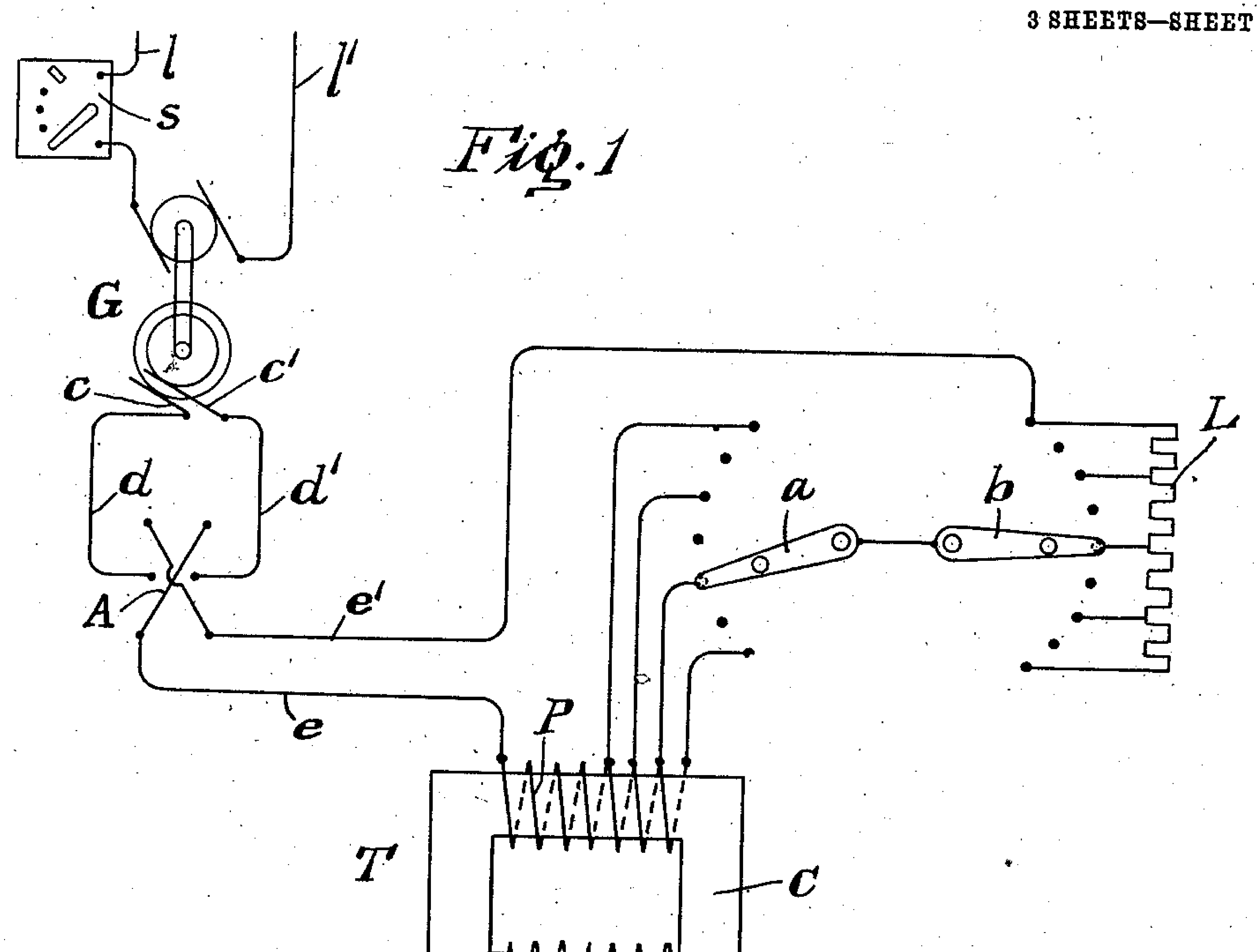
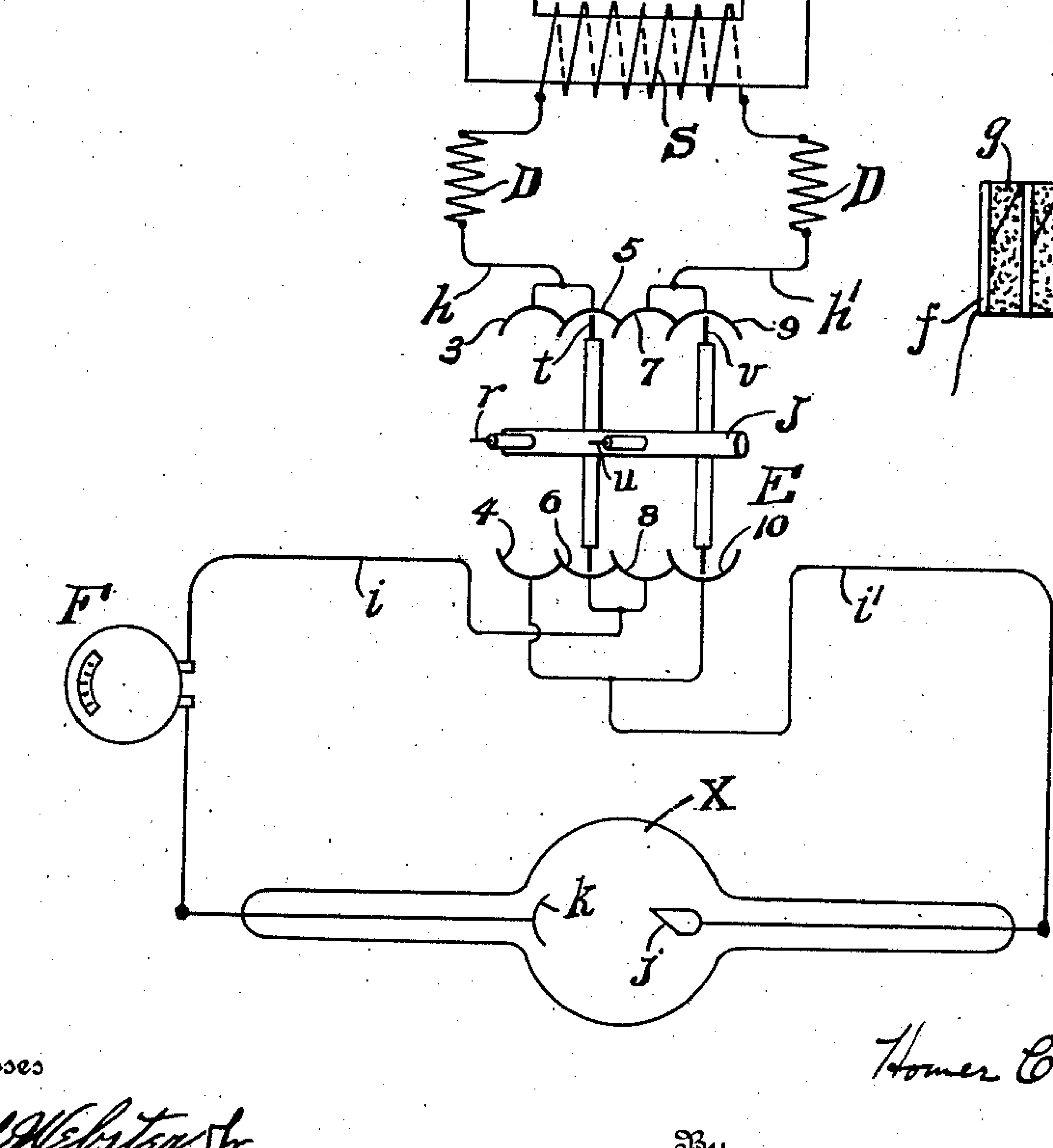
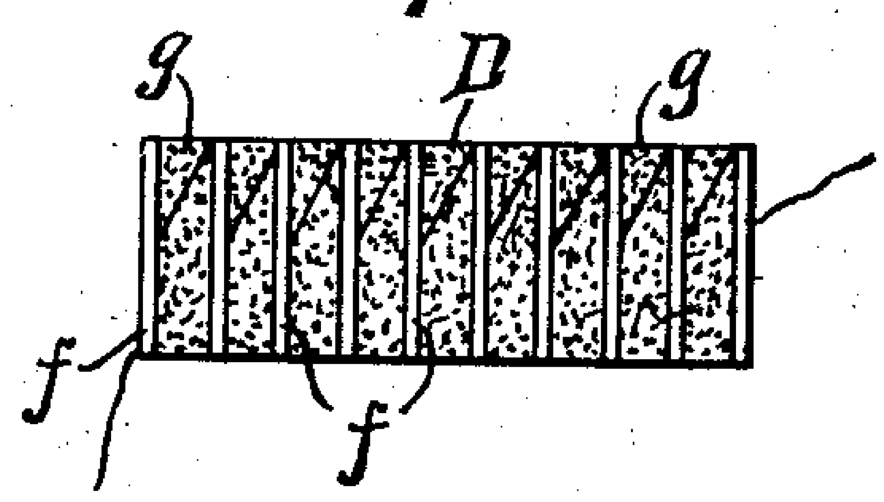



Fig. 4.



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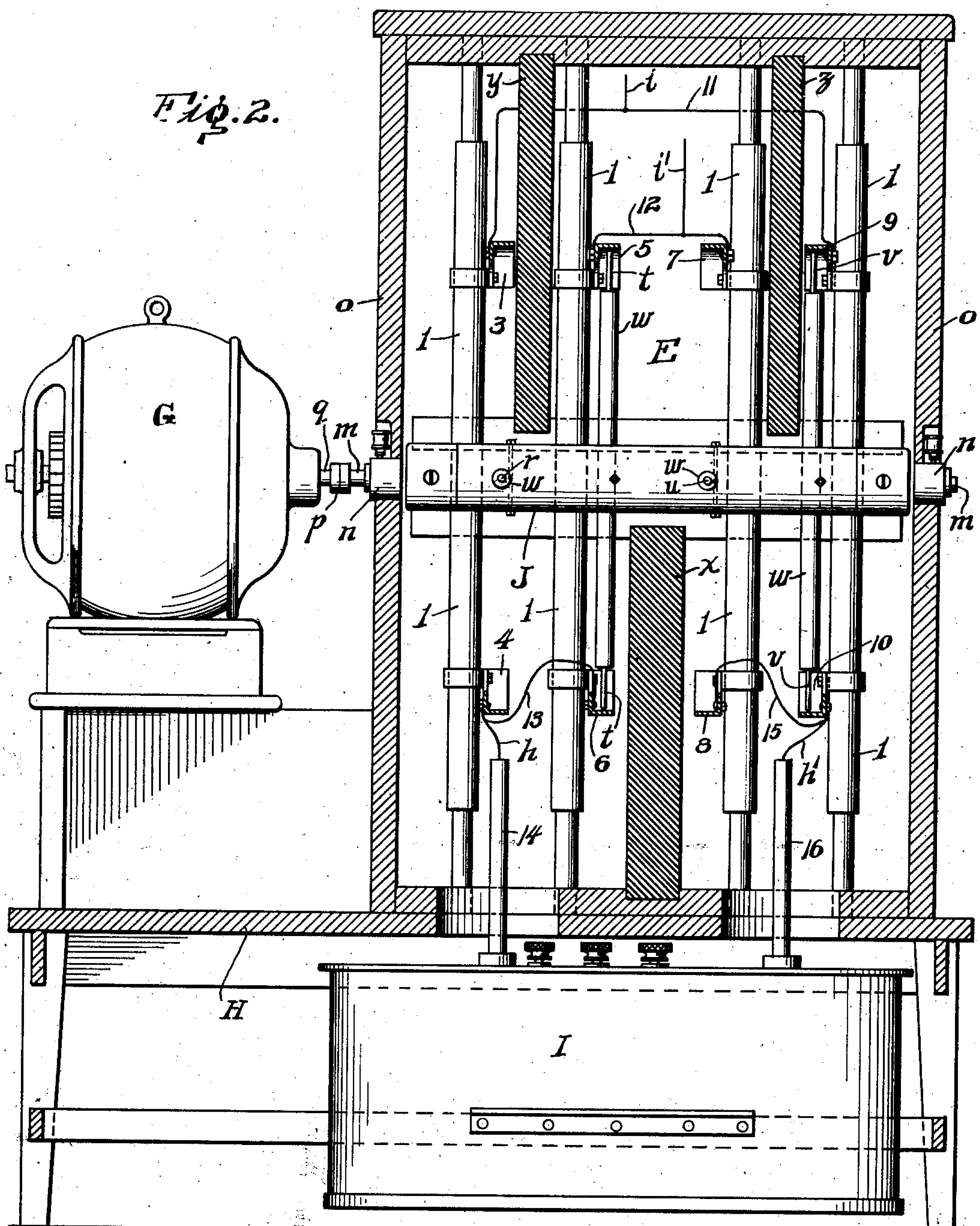
3 SHEETS—SHEET 2.

Fig. 2.



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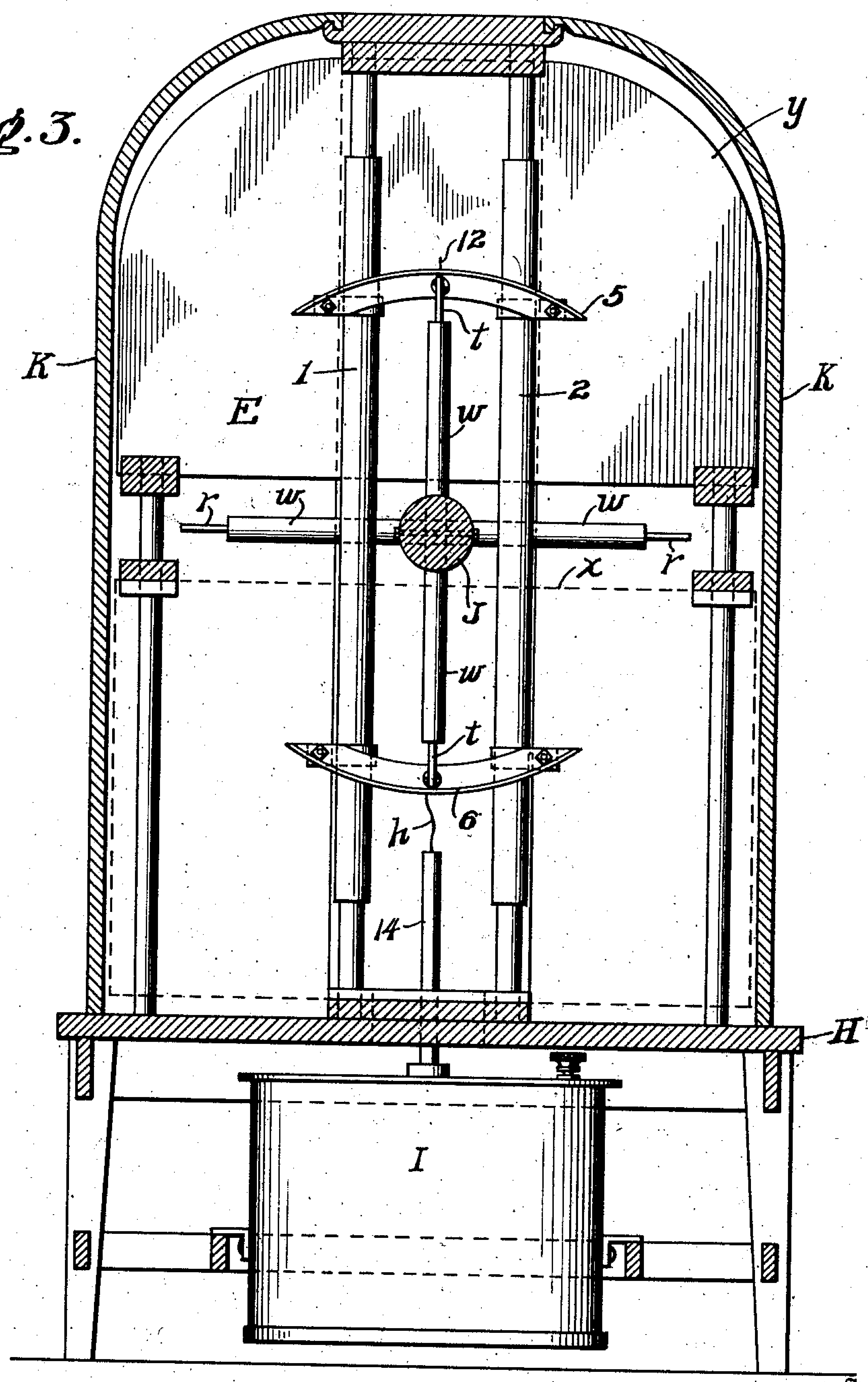
3 SHEETS—SHEET 3.

Fig. 3.



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UNITED STATES PATENT OFFICE.

HOMER CLYDE SNOOK, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO ROENTGEN MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

X-RAY SYSTEM.

954,056. Specification of Letters Patent. **Patented Apr. 5, 1910.**

Application filed July 20, 1907. Serial No. 384,802.

To all whom it may concern:

Be it known that I, HOMER CLYDE SNOOK, a citizen of the United States, residing at Philadelphia, county of Philadelphia, and State of Pennsylvania, have invented certain new and useful Improvements in X-Ray Systems, of which the following is a specification.

My invention relates to a system for producing X-rays, and has particular reference to the production of very intense X-rays with a maximum efficiency of conversion.

My invention resides in means for exciting an X-ray tube at a much higher current density than has been heretofore practiced in the art, with greatly increased usefulness, both in the direction of greatly reducing periods of exposure, and rendering visible the interior of denser or thicker masses, and otherwise.

My invention resides in an X-ray system in which the transformer has minimum magnetic leakage, in combination with a rectifying switch driven in synchronism and definite phase relation with the current supply, preferably by mechanically connecting the rotating member of the switch to the rotating member of a current generator. These features, along with features of the rectifying switch contribute to efficiency of conversion in the X-ray tube, by preventing inverse discharge in the tube; and by my system all of the current waves are passed through the X-ray tube all in the same direction, and without any inverse discharge, so that the intensity of excitation is a maximum.

For an illustration of one of the forms my invention may take reference is to be had to the accompanying drawings, in which:

Figure 1 is a diagrammatic view illustrating the apparatus and circuit arrangements of the system. Fig. 2 is a vertical sectional view, partly in elevation, of the high potential rectifying or pole changing switch as mounted in operative relation with a motor, inverted rotary or other suitable device, and the high potential transformer. Fig. 3 is an end elevational view, partly in section, of the high potential pole changing switch or rectifier as shown in Fig. 2. Fig. 4 is a view of a secondary choke coil.

Referring to Fig. 1, *l*, *l'* are the conductors of an electric supply circuit, in this instance of direct current. A starting box, shown conventionally at *s*, intervenes in the direct current side of the motor generator or inverted rotary G. If a motor generator, it comprises a direct current motor driving an alternating current generator. If an inverted rotary, it comprises a direct current armature having suitable taps taken off to slip rings in a well known manner. In either case, the alternating current is delivered by the slip contacts *c c'* to the conductors *d d'*. An ordinary reversing switch A, hand operated, intervenes between the conductors *d d'* and the conductors *e e'*. Connected in series with the conductors *e e'* is the primary winding P of a transformer T whose core is C and whose secondary winding is S. A switch arm or lever *a* serves to cut in or out turns of the primary winding P; and a switch arm or lever *b* serves to cut in or out more or less of the non-inductive resistance L for controlling the current strength in the transformer primary circuit. As shown, the transformer T has a closed magnetic circuit, and this is the preferred form, though other types of transformer are comprehended in my invention. By using the closed magnetic circuit type the mutual induction between the primary and secondary windings is made very great, the magnetic leakage being very small. This insures a shifting of phase of secondary current with respect to secondary electromotive force, which is only slight, if anything. With this type of transformer the magnetizing current at all times is a minimum, thus requiring less volt-ampere capacity and output of the machine G. Reactance or choke coils D, D are connected in series with the secondary of the transformer. These reactances have no iron present and offer a self-induction to any high frequency oscillations, preventing such high frequency oscillations running back to the secondary winding and puncturing the insulation thereof or causing other breakdown. These reactances D, D are preferably constructed of axially short coils, which might be called pancake coils, connected in series with each other but the separate coils or windings are so widely separated from each other, either by air or suitable dielectric, such as wax, resin, etc., or mixtures of the same, that the capacity between neighboring coils is so slight that there will not be a capacity or condenser path through the coils, from one coil to another. In other words, if the coils were placed close together, or if the winding was one long continuous coil, the oscillations might succeed in passing the coil to the secondary S of the transformer without passing through the conductor of the reactance coils. This construction is represented in Fig. 4 where the pancake coils *f f* are shown in edge view and separated by a suitable dielectric material *g g*. The separation of the coils *f*, *f* as described, is productive of the further advantage that the self-induction as regards the low transformer frequency is a minimum, while as to high frequency oscillations the self-induction is a maximum. The current from the transformer secondary S is available from the conductors *h h'* which lead to the terminals of a high potential pole changing or rectifying switch shown in Fig. 1 at E, and one form of which is shown in Figs. 2 and 3 in detail. This rectifying or pole changing switch E is driven in synchronism with the current of either the primary or secondary of the transformer T. From the pole changing switch E the conductors *i i'* lead to the terminals of the X-ray tube X, whose cathode is *k* and whose anode is *j*. An ammeter F is connected in series between the conductor *i* and the cathode *k* and serves to measure the amount of current passed through the tube X. This ammeter F may be constructed similarly to a D'Arsonval galvanometer or meter as modified in accordance with Letters Patent of the United States No. 768,957.

Referring to Fig. 2, a bench or base H, of wood or other suitable material, serves to support the high potential rectifying or pole changing switch, the transformer T, (contained, along with the reactances D, D in the metal transformer case I) and the motor generator or inverted rotary G. In Fig. 2 G is shown as an inverted rotary receiving direct current and delivering alternating current. A wooden spindle or shaft J has metal shaft terminals *m m* having bearings *n n* supported by the end walls *o o* of the wooden covering or casing for the high potential pole changing switch E. One of the terminal shafts *m* is connected by an insulating coupling *p* with the shaft *q* of the inverted rotary G. Extending through and carried by the spindle J are four metallic rods or wires *r*, *t*, *u* and *v* incased in rubber or other insulating covering and support *w*. In Fig. 2 the conductors *t* and *v* are shown in vertical position while the conductors *r* and *u* are shown horizontal, the pairs being always at right angles to each other. The four conductors and their coverings and the wooden spindle J are all mechanically balanced so that the center of gravity of the moving system is in the axis of the moving spindle J. Vertically extending rods or members 1 and 2 of insulating material are arranged parallel with each other and support similar conducting arcs 3 and 4 disposed above and below the spindle J. There are four pairs of vertical supports 1 and 2 supporting similar and similarly placed conducting arcs 5, 6—7, 8 and 9, 10. The conducting arcs 3 and 9 are connected together by conductor 11 from which leads one of the two conductors *i*. Conducting arcs 5 and 7 are connected together by conductor 12 with which communicates the conductor *i'*. The conducting arcs 4 and 6 are connected together by conductor 13 to which is also connected the conductor *h* led up through the insulating tube 14 through the cover of the oil tank I from one terminal of the secondary S of the transformer T. Similarly, the conducting arcs 8 and 10 are connected together by the conductor 15 with which communicates the conductor *h'* led up through the insulating tube 15 from the tank I forming the other terminal of the secondary S. As the spindle J is rotated by the inverted rotary G the conducting rods *r*, *t*, *u* and *v* rotate in front of their respective pairs of conducting arcs and in close proximity thereto, though not in actual mechanical contact therewith. The angular extent of the conducting arcs from tip to tip is slightly less than 90 degrees. Between the conducting arcs 4, 6 and 8, 10 the full potential difference of the secondary S exists. For this reason a heavy insulating screen *x* composed of mica, glass, or other suitable material intervenes between them and extends well up toward the spindle J. The same great difference of potential exists between the neighboring conducting arcs 3, 5 and 7, 9 and between each pair is disposed a similar insulating screen *y*, *z*. The disposal of the high potential switch, the inverted rotary and the transformer, as shown upon the bench or support H, is a most convenient and advantageous one, and particularly when it is desired that the apparatus shall be portable or movable from room to room, in which case rollers or casters are supplied upon the feet of the bench H. The ammeter F is conveniently disposed upon the top of the casing or wooden covering K for the high potential switch.

The operation is as follows: The operator closes any suitable switch whereupon the conductors *l*, *l'* are thrown into communication with a source of current, and then the lever of the starting box *s* is moved to cut out resistance in a well known manner, whereupon the motor generator or inverted rotary comes up to full speed. This simultaneously sets the spindle J into operation. Upon closing the reversing switch A by hand, either in the one position or the other, the transformer T is energized and the secondary winding S delivers current at high potential to the lower conducting arcs of the mechanical rectifier or high potential switch E.

The switch E, through its upper conducting arcs, delivers current to the X-ray tube X through the ammeter F always in the same direction, that is to say, all of the half waves of the alternating current are passed through the tube X and all of them always in the same direction. If it is found at starting that the direction of the current through the tube X is wrong, as is manifested by a mere glance at the tube, the operator needs simply to throw the switch A to its other position whereupon the current will pass through the tube in the proper direction, producing intensest X-rays.

As previously stated, the leakage in the transformer T is a minimum and, therefore, the mutual induction between primary and secondary is a maximum. This means a resulting minimum of phase displacement of the current with respect to the electromotive force in the secondary S. But for whatever slight phase displacement there may be, the fact that the conducting arcs of the high potential switch are slightly less than 90 degrees (the inverted rotary G being a four-pole machine) insures that a potential wave shall exist in the secondary S for a slight interval of time before any current passes through the cross connectors r, t, u, v of the switch E to the tube X. These features of very small, if any, phase displacement between current and electromotive force in the secondary S and the conducting arcs of angular length slightly less than a half wave of current guarantee that there will be no inverse discharge in the tube X, each of these features contributing to that end. The operator exercises control of the secondary potential by adjusting the switch lever a to include more or less primary turns; and he exercises control as to current strength in the primary P by adjusting the non-inductive resistance L.

With the parts of the switch E in the position shown in Fig. 2, the transformer T is delivering current at the maximum of a half wave through the conductor h to the arc 6 through the cross connector t to the arc 5, and thence by conductors 12 and i to one terminal of the tube, the return being through the conductor i', conductor 11 to arc 9, through cross connector r to the arc 10 and thence by conductor h' to the other terminal of the secondary. By the arrangement shown the high potential switch members r, t, u and v rotate in synchronism with the alternating current delivered by G and the spindle J is secured by the coupling p in definite angular position with respect to the windings of G delivering alternating current. This phase relation or angular position may be adjusted by the coupling p.

Obviously, the motor generator or inverted rotary G may be placed at a distance from the switch E and the spindle J driven by a synchronous motor deriving its current from G, though such arrangement is not so effective in preventing inverse discharge in the tube as where a mechanical connection is employed. Obviously, also the connection between the shaft q of the machine G with the spindle J need not be a direct mechanical one, but may be an indirect mechanical one as by belt, gears, chain, or other suitable means, it being necessary only to insure synchronism of the spindle J with the shaft q, and in the proper angular phase relation. Or the spindle J may be driven by any suitable motor, as a direct current motor or an asynchronous alterating current motor, and a damping or control device applied to the spindle J to prevent hunting or getting out of step. Such a device may be a field having poles excited by alternating current, having a rotating member having wound or unwound poles. Furthermore, the conductors l, l' may communicate with an alternating current and supply current to an induction motor to drive an alternating current generator of a different frequency from the supply, the spindle J being connected to the shaft of the alternating current generator. Or the induction motor may drive the spindle J and a synchronizing device, such as a small synchronous motor, or the device just previously described, may act upon the spindle J to keep it in synchronism or proper speed. It is obvious also that a source of direct current may be employed in connection with the transformer primary, a pole changing switch and interrupter being included in the circuit and driven or operated at desired speed, with a high tension pole changing switch or rectifier in the secondary circuit synchronous with the switch and interrupter in the primary circuit.

While the switch E is shown with only three insulating barriers and with the conducting arcs all in line and the pairs of rotating cross connectors at 90 degrees with each other, it is to be understood that the two pairs of conducting arcs may be shifted around through 90 degrees and the rotating cross connectors all arranged in line with each other, and in such case five insulating barriers will be required.

What I claim is

1. In an X-ray system, the combination with a source of fluctuating or alternating current, of a high tension transformer having very small magnetic leakage, an X-ray tube, and a synchronous rectifying switch comprising conducting arcs and associated cross connectors, the angular extent of an arc corresponding with a length slightly less than a current wave, whereby all current waves are passed through said tube and all in the same direction, and whereby inverse discharge in said tube is prevented.

2. In an X-ray system, the combination

with supply conductors, of a dynamo electric converter for delivering fluctuating or alternating current, an associated high potential transformer having small magnetic leakage, an X-ray tube, and a synchronous high potential rectifying switch causing the passage of all the current waves through said tube and all in the same direction.

3. In an X-ray system, the combination with a source of fluctuating or alternating current, a high potential transformer having small magnetic leakage, an X-ray tube, and a synchronous high potential switch controlling the passage of current through said tube, said switch having conducting arcs of angular extent corresponding with substantially an entire current wave.

4. The combination with a source of fluctuating current, of a high potential rectifying switch comprising conducting arcs and coöperating cross connectors, means for causing relative rotation between said arcs and cross connectors in synchronism with said current, said conducting arcs of said switch having an angular extent corresponding with a length slightly less than a current wave.

5. In an X-ray system, the combination with a source of alternating or fluctuating current, of a high tension transformer supplied thereby, said transformer having small magnetic leakage, an X-ray tube, and a rectifying switch, comprising conducting arcs of substantial angular extent and associated rotating cross connectors, directing all of the current waves through said tube and all in the same direction.

6. In an X-ray system, the combination with a generator of fluctuating or alternating current, of a transformer having small magnetic leakage, an X-ray tube, and a rectifying switch for directing all the current waves from said transformer through said tube and all in the same direction, the rotating member of said switch being driven in definite mechanical relation with the rotating member of said generator.

7. In an X-ray system, the combination with a generator of fluctuating or alternating current, of a transformer having small magnetic leakage supplied thereby, an X-ray tube, and a rectifying switch directing all the current waves from said transformer through said tube, the rotating switch member being driven in definite mechanical relation with the rotating member of said generator.

8. In an X-ray system, the combination with a generator of fluctuating or alternating current, of a transformer, an X-ray tube, and a rectifying switch directing all of the current waves from said transformer and substantially all of each wave through said tube, the rotating member of said switch being driven in definite mechanical relation with the rotating member of said generator.

9. In an X-ray system, the combination with a generator of alternating or fluctuating current, of a high tension transformer having small magnetic leakage, an X-ray tube, and a high potential rectifying switch directing all of the current waves from said transformer through said tube and all in the same direction, the rotating member of said switch being driven in definite mechanical relation with the rotating member of said generator.

10. In an X-ray system, the combination with a generator of fluctuating or alternating current, of a transformer having small magnetic leakage, an X-ray tube, and a rectifying switch directing all the current waves from said transformer through said tube and all in the same direction, the rotating member of said switch being mechanically connected with the rotating member of said generator.

11. In an X-ray system, the combination with a generator of alternating or fluctuating current, of a high tension transformer having small magnetic leakage, an X-ray tube, and a high potential rectifying switch directing all the current waves from said transformer through said tube and all in the same direction, the rotating member of said switch being mechanically connected with the rotating member of said generator.

12. In an X-ray system, the combination with a current supply, of a dynamo electric converter delivering fluctuating or alternating current, a transformer deriving current from said converter, an X-ray tube, and a rectifying switch directing all the current waves from said transformer through said tube, the rotating member of said switch being driven in definite mechanical relation with the rotating member of said converter.

13. In an X-ray system, the combination with a current supply, of a dynamo electric converter delivering alternating or fluctuating current, a transformer, an X-ray tube, and a rectifying switch directing all the current waves from said transformer through said tube and all in the same direction, the rotating member of said switch being driven in definite mechanical relation with the rotating member of said converter.

14. In an X-ray system, the combination with a current supply, of a dynamo electric converter delivering fluctuating or alternating current, a transformer having small magnetic leakage, an X-ray tube, and a rectifying switch directing substantially all the energy from said transformer through said tube and all in the same direction, the rotating member of said switch being driven in definite mechanical relation with the rotating member of said converter.

15. In an X-ray system, the combination with a current supply, of a dynamo electric converter delivering fluctuating or alternating current, a transformer, an X-ray tube, and a rectifying switch directing all the current waves from said transformer through said tube, the rotating member of said switch being mechanically connected with the rotating member of said converter.

16. In an X-ray system, the combination with a generator of fluctuating or alternating current, of a transformer having small magnetic leakage, an X-ray tube, and a rectifying switch directing substantially all of the energy from said transformer through said tube and all in the same direction, the rotating member of said switch being driven in definite mechanical relation with the rotating member of said generator.

17. In an X-ray system, the combination with a generator of fluctuating or alternating current, of a transformer having small magnetic leakage, an X-ray tube, and a rectifying switch directing all the current waves from said transformer through said tube and all in the same direction, the rotating member of said switch being driven in definite mechanical relation with the rotating member of said generator.

18. In combination with a source of alternating or fluctuating current, a synchronously driven switch comprising pairs of conducting arcs and coöperating cross connectors disposed at 90 degrees with respect to each other, the moving member of said switch being mechanically coupled to the rotating member of said source of current and so related to the current from said source that 90 mechanical degrees in said switch correspond with 180 electrical degrees of said current.

19. In a high potential electric switch, pairs of opposed conducting arcs, said pairs being disposed in alinement with each other, and coöperating rotating cross connectors disposed at right angles to each other.

20. In a high potential electric switch, pairs of opposed conducting arcs, an insulating barrier disposed between neighboring arcs of different pairs, and rotating cross connectors coöperating with said arcs.

21. In a high potential electric switch, pairs of opposed arcs, the arcs of the different pairs disposed in alinement with each other, an insulating barrier between neighboring arcs of different pairs, and rotating cross connectors coöperating with said arcs and disposed at right angles to each other.

22. In a high potential rectifying switch, four pairs of opposed arcs, an insulating barrier between neighboring arcs of different pairs at different potentials, and rotating cross connectors coöperating with said arcs.

23. In a high potential rectifying switch, four pairs of opposed arcs, the arcs of the different pairs being disposed in alinement with each other, and three insulating barriers disposed respectively between neighboring arcs at different potentials, and four rotating cross connectors coöperating with said arcs, the neighboring cross connectors being disposed at right angles with respect to each other.

24. In combination with a source of fluctuating current, a synchronously driven rectifying switch comprising opposed pairs of conducting arcs having an angular extent corresponding to slightly less than the current wave, and coöperating rotating cross connectors disposed at right angles to each other, said cross connectors being supported and driven by an insulating shaft, and said cross connectors being themselves insulated throughout nearly their entire lengths.

25. In combination with a source of fluctuating current, a synchronously driven rectifying switch comprising pairs of opposed conducting arcs, said pairs being disposed in alinement with each other, and coöperating rotating cross connectors, an insulating shaft for supporting and driving said cross connectors, said cross connectors being themselves insulated throughout nearly their entire lengths, and insulating barriers between conducting arcs subjected to substantial differences of potential.

26. In a high potential rectifying switch, four pairs of opposed arcs, the arcs of the different pairs being disposed in alinement with each other, and three insulating barriers disposed respectively between neighboring arcs at different potentials, and four rotating cross connectors insulated throughout nearly their entire lengths and coöperating with said arcs, neighboring cross connectors being disposed at right angles with respect to each other.

27. In a high potential rectifying switch, pairs of opposed conducting arcs, an insulating barrier disposed between neighboring arcs of different pairs, an insulating shaft, and cross connectors coöperating with said arcs rotated by said shaft and insulated throughout nearly their entire lengths.

28. In a high potential rectifying switch, pairs of opposed arcs, the arcs of the different pairs disposed in alinement with each other, an insulating barrier between neighboring arcs of different pairs, an insulating shaft, and cross connectors coöperating with said arcs rotated by said shaft and insulated throughout nearly their entire lengths.

29. In an X-ray system, the combination with a generator of fluctuating current, of a transformer having small magnetic leakage and deriving current from said generator, an X-ray tube, a high potential rectifying

switch intervening between the transformer secondary and said X-ray tube for directing all the current waves through said tube and all in the same direction, and means for driving the rotating switch element in definite angular relation with the rotating element of said generator.

30. In an X-ray system, the combination with a generator of fluctuating current, of a transformer having small magnetic leakage and deriving current from said generator, an X-ray tube, a high potential rectifying switch intervening between said transformer secondary and said X-ray tube for directing all the current waves through said tube and all in the same direction, and a mechanical connection between the rotating elements of said generator and of said switch.

31. In an X-ray system, the combination with a generator of fluctuating current, of a transformer deriving current therefrom, an X-ray tube, a high potential rectifying switch, said switch comprising pairs of conducting arcs and coöperating connectors, said arcs and connectors being rotatable with respect to each other, said switch directing all the current waves through said tube and all in the same direction, and means for driving the rotatable switch element in definite mechanical relation with the rotating element of said generator.

32. In an X-ray system, the combination with a generator of fluctuating current, of a transformer having small magnetic leakage deriving current therefrom, an X-ray tube, a high potential rectifying switch, said switch comprising pairs of conducting arcs and coöperating connectors, said arcs and connectors being rotatable with respect to each other, said switch directing all the current waves through said tube and all in the same direction, and means for driving the rotating switch element in definite mechanical relation with the rotating element of said generator.

33. In a high potential rectifying switch, coöperating relatively rotating arcs and connectors, an insulating driving shaft, and barriers between arcs and connectors subjected to widely different potentials.

34. In a high potential rectifying switch, coöperating pairs of arcs and connectors, means for rotating said arcs and connectors with relation to each other, barriers between arcs subjected to widely different potentials, the arcs or connector of one pair being disposed mechanically at an angle with the arcs or connector of another pair corresponding with the angle of phase difference between the current waves to be rectified.

35. In a high potential rectifying switch, coöperating relatively rotating pairs of arcs and connectors, and an insulating barrier between neighboring arcs of different pairs at different potentials.

36. The combination with a generator of fluctuating current, of a step up transformer having small magnetic leakage and deriving current from said generator, a translating device, a high potential rectifying switch intervening between the transformer secondary and said translating device for directing all the current waves through said translating device and all in the same direction, and means for driving the rotating switch element in definite angular relation with the rotating element of said generator.

37. The combination with a generator of fluctuating current, of a step up transformer having small magnetic leakage and deriving current from said generator, a translating device, and a high potential rectifying switch intervening between the transformer secondary and said translating device for directing all the current waves through said translating device and all in the same direction.

38. The combination with a generator of fluctuating current, of a step up transformer deriving current from said generator, a translating device, a high potential rectifying switch intervening between the transformer secondary and said translating device for directing all the current waves through said translating device and all in the same direction, and means for driving the rotating switch element in definite angular relation with the rotating element of said generator.

39. The combination with a generator of fluctuating current, of a transformer having small magnetic leakage and deriving current from said generator, a translating device, and a high potential rectifying switch intervening between the transformer secondary and said translating device for directing substantially all of each current wave through said translating device and all the current waves in the same direction.

40. The combination with a generator of fluctuating current, of a step up transformer deriving current from said generator, a translating device, a high potential rectifying switch intervening between the transformer secondary and said translating device for directing substantially all of each current wave through said translating device and all the current waves in the same direction, and means for driving the rotating switch element in definite angular relation with the rotating element of said generator.

In testimony whereof I have hereunto affixed my signature in the presence of the two subscribing witnesses.

HOMER CLYDE SNOOK.

Witnesses:
Eleanor T. McCall,
Anna E. Steinbock.

Disclaimer in Letters Patent No. 954,056.

DISCLAIMER.

954,056.—*Homer Clyde Snook*, Philadelphia, Pa. X-RAY SYSTEM. Patent dated April 5, 1910. Disclaimer filed December 31, 1915, by *Snook-Roentgen Manufacturing Company*, assignee by mesne assignments.

Enters this disclaimer:

"To that part of the specification printed at page 3, lines 98 to 106, inclusive, and reading as follows:

"It is obvious also that a source of direct current may be employed in connection with the transformer primary, a pole changing switch and interrupter being included in the circuit and driven or operated at desired speed, with a high tension pole changing switch or rectifier in the secondary circuit synchronous with the switch and interrupter in the primary circuit."

[*Official Gazette, January 11, 1916.*]